Bilateral Trade Imbalances*

Alejandro Cuñat† Robert Zymek‡

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Abstract

Bilateral trade imbalances are determined by aggregate trade imbalances, production and expenditure patterns, and trade barriers. We calibrate a dynamic many-sector trade model to match the recent sectoral trade and production shares of 40 economies and the rest of the world. Through a variance decomposition and counterfactuals, the model allows us to assess the relative importance of these determinants for the observed variation in bilateral imbalances. Large pairwise asymmetries in residual trade "wedges" are needed for the model to match the data. These account for roughly 60% of the variation, with most of the rest due to differences in production and expenditure patterns. Aggregate trade imbalances play a minor role. A counterfactual trade policy which eliminates trade-wedge asymmetries would have sizeable effects on bilateral trade patterns and welfare. However, it would leave aggregate trade balances virtually unchanged.

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†Department of Economics, University of Vienna and CESifo, Oskar Morgenstern Platz 1, Vienna 1090, Austria; alejandro.cunat@univie.ac.at.

‡School of Economics, University of Edinburgh and CESifo, 31 Buccleuch Place, Edinburgh, EH8 9JT, United Kingdom; robert.zymek@ed.ac.uk.

1 Introduction

It is a well-known fact that the U.S. trade balance has been in deficit every year since 1992. In the five years between 2010 and 2014, that deficit amounted to 3% of GDP. What is perhaps less well known is that the overall U.S. deficit masks significant heterogeneity of its trade balance with individual partner countries. The vertical bars in Figure 1 represent the U.S. trade balance (as a percentage of U.S. GDP) vis-à-vis 39 other economies and the rest of the world (RoW) over the period 2010-2014.[1] There is significant variation in U.S. bilateral net exports around their average value, represented by the thick horizontal line.[2] The U.S. runs large bilateral deficits with China, and its NAFTA partners Mexico and Canada − but it also runs small trade surpluses with a number of other economies, including Ireland, the Netherlands and France.

[Insert Figure 1 here]

Such dispersion in a country's bilateral balances with its trade partners is not peculiar to the U.S. case. Each light-blue dot in Figure 2 represents the trade balance of the horizontal-axis country with one of its trade partners (as a percentage of the horizontal-axis country's GDP). The large black dot represents the horizontal-axis country's average bilateral balance. As the figure shows, the differences between the bilateral balances of individual countries with their partners are significantly larger than the differences in average bilateral balances *across* countries. Yet so far there exists no formal study which attempts to account for the large observed variation in trade balances across country pairs − despite the fact that specific examples of major imbalances between trade partners are a recurrent trigger of political controversies.[3]

[Insert Figure 2 here]

The present paper seeks to fill this gap in the literature. We set up a dynamic many-country, many-sector quantitative trade model. This model is combined with sectoral-level data on production, spending and trade for 40 countries and the rest of the world from the World Input Output Database (WIOD). Through a static variance decomposition and (with stronger assumptions) through fully-fledged counterfactuals, we are able to show that a large share of the variation in bilateral trade balances is

[1] The figure is based on data from the 2016 release of the World Input-Output Database (WIOD). Section 3 discusses our data sources in detail.

[2] Since the data represented in Figure 1 covers the total value of all U.S. exports and imports divided across 40 countries/regions, the average bilateral trade balance equals the overall U.S. trade balance divided by 40.

[3] In the last three decades, the U.S. trade deficit vis-à-vis Japan (Janow, 1994), China (Feenstra et al., 1998; Hughes, 2005) and, most recently, Germany (Swanson, 2017; Krugman, 2017) has been in the spotlight as a possible symptom of unfair trade practices on the part of these countries against American producers.

the result of observed differences in country's aggregate trade balances, spending patterns and industrial structure. Nevertheless, over half of the variation in bilateral balances remains unexplained − and our model attributes it to pairwise asymmetric impediments to trade.

There are three possible reasons why trade balances may vary across country pairs. First, differences in aggregate trade balances may give rise to pairwise differences in bilateral balances: by definition, overall-deficit countries − such as the U.S. − will have a deficit with their average trade partner; overall-surplus countries − such as China − will have a surplus. Everything else constant, we would thus expect a deficit-surplus pair to have a larger trade imbalance than two surplus or two deficit countries. Second, differences in sectoral expenditure and production patterns may give rise to bilateral imbalances: if a large portion of Dutch expenditure is dedicated to goods produced by the U.S., a large portion of German expenditure to goods produced by the Netherlands, and a large portion of U.S. expenditure to goods produced by Germany, the resulting "triangular trade" may give rise to bilateral imbalances even in the absence of overall trade surpluses and deficits. Third and finally, systematically asymmetric obstacles to trade between two countries may penalise bilateral trade flows in one direction more than in the other.

Our calibrated model allows us to capture all three explanations for bilateral trade imbalances. We use the model's preference and technology parameters to match counties' aggregate trade surpluses and deficits perfectly, and to explain as much of countries' sector-level patterns of spending, production and trade as possible. The remaining gap between the model and the data is ascribed to the presence of broadly defined trade "wedges" at the country-pair-sector level. These wedges may represent technological and policy barriers to trade, as well as preference differences across countries which could reduce the gains from trade in some sectors. Our calibration treats them as a "residual," explaining the portion of the value of a country's import from its trade partner which cannot otherwise be accounted for. In order to match all flows of goods and services perfectly, we need to allow for these wedges to be potentially asymmetric: in a given sector, the import wedge faced by one country from another may differ from the wedge faced by the second from the first. In a standard quantitative trade model, these three features of the data span all possible explanations for (differences in) bilateral trade imbalances: if there were no aggregate trade surpluses and deficits, if all countries' production and expenditure patterns were the same, and if trade wedges were symmetric within country pairs, all bilateral balances would be identically equal to zero.

Having devised a model which perfectly matches all sector-level bilateral trade flows, we first carry out an accounting exercise which decomposes the observed variation in bilateral trade balances into the individual and combined effects of the three

drivers described above. We find that overall trade surpluses and deficits on their own account for a small share of the variance (roughly 2%). The individual contribution of triangular trade is sizeable (roughly 12%), but the largest individual share is due to asymmetries in trade wedges (roughly 38%). The remainder of the variance is due to differences in the so-called "multilateral resistance terms", which reflect the interactive effect of all three. This static accounting decomposition provides a first indication that asymmetries in trade wedges are required to explain a significant portion of differences in trade imbalances across country pairs. The asymmetries do not appear to be systematically related to country-pair characteristics, and their quantitative importance changes little over time.

To investigate the role of trade-wedges (and their asymmetries) further, we perform counterfactuals which allow us to investigate changes in the distribution of bilateral trade balances in response to changes in trade barriers. These counterfactuals capture the impact of trade-wedge changes on "multilateral resistance" as well as general-equilibrium effects on global investment patterns and aggregate trade balances. For the latter, we rely on the intertemporal component of our model, which assumes that capital is internationally mobile and allows for trade surpluses and deficits to arise in steady state as the result of differences in countries' production technologies and intertemporal preferences. In the paper, we report the impact on steady-state trade patterns of two such trade-policy experiments: a hypothetical rise in trade barriers which makes all trade wedges bilaterally symmetric; and the actual rise in trade barriers as a result of the on-going U.S.-China trade war.

Our first policy experiment shows that, in a counterfactual world economy with completely symmetric wedges, 60% of the variation of bilateral trade balances would disappear. However, aggregate trade balances would remain virtually unchanged. As a result, countries' overall trade surpluses and deficits are merely distributed more evenly across their trade partners. Our results indicate that most of the remaining differences in bilateral balances in this world are the result of "triangular trade". We also find that the global move to trade-wedge symmetry would have sizeable effects on countries' real GDPs and consumption levels. Taken together, these findings imply that the model-implied trade-wedge asymmetries are significant for bilateral trade patterns and welfare − and may require further study. Our second experiment shows that, if the new U.S.-China tariffs remain in place, they will significantly reduce the U.S.-China trade deficit in the long run. However, they will also cause bilateral net exports with all other U.S. trade partners to deteriorate − and reduce both U.S. and Chinese real consumption by a fifth of a percent.

Bilateral trade imbalances have received surprisingly little attention in academic research. Two notable exceptions are Feenstra et al. (1998), and Davis and Weinstein (2002). Feenstra et al. (1998) focus exclusively on the case of the U.S. trade deficit

with China, whereas Davis and Weinstein (2002) analyse bilateral imbalances for a large sample of countries. Their work is most closely related with ours. They provide rough calculations of "theory-predicted" bilateral imbalances, relying on the gravity model of trade, and contrast them with the actual imbalances observed in the data. As we show, their calculations are not inconsistent with the theoretical framework we employ − in which the values of sector-level trade flows between countries also obey a gravity equation −, but they are incomplete since their gravity equation is not derived from a fully microfounded quantitative model.[4] Moreover, Davis and Weinstein focus exclusively on trade in goods, while use of WIOD data allows us to cover the total value of countries' imports and exports of both goods and services. Our work can be understood as embedding their analysis in a fully structural model which allows for theory-consistent variance decompositions and counterfactuals.

The present paper belongs to a large and growing strand of research, reaching back to Eaton and Kortum (2002), which uses calibrated quantitative models of international trade to analyse the relationship between countries' sector-level productivities, bilateral trade costs and real incomes. Several papers in this literature − including Dekle et al. (2007, 2008), Eaton et al. (2016a), and Cuñat and Zymek (2018) − explore the impact of (changes in) *aggregate* trade imbalances on countries' incomes. Some analyse the impact of (changes in) trade costs on *aggregate* trade imbalances − following on from the classic paper by Obstfeld and Rogoff (2000).[5] Yet to the best of our knowledge, none explore the determinants of *bilateral* trade balances; and few investigate the prevalence and macroeconomic implications of asymmetric trade barriers.

A notable exception is Waugh (2010), who shows that asymmetric trade barriers between rich and poor countries can help better reconcile quantitative trade models with countries' observed aggregate import shares. He demonstrates that removing them would potentially reduce international income differences significantly. Our findings are complementary with Waugh's analysis (2010), which abstracts from trade imbalances, insofar as they illustrate that trade-wedge asymmetries are also required to account for a portion of countries' bilateral trade surpluses and deficits. Moreover, we find that such asymmetries may not only shape trade between rich and poor countries, but also sector-level trade patterns between developed economies.

The remainder of the paper is structured as follows. Section 2 presents the the-

[4] Anderson (1979), and Anderson and van Wincoop (2003) were the first to show that model-consistent gravity equations feature so-called "multilateral resistance terms" − reflecting differences in price levels faced by different countries −, and that their omission may significantly alter the findings derived from applying the gravity equation to empirical data. In a recent manuscript, Felbermayr and Yotov (2019) also highlight the omission of multilateral resistance terms as a short-coming of the analysis performed by Davis and Weinstein (2002).

[5] See Reyes-Heroles (2016), Eaton et al. (2016b) and Ravikumar et al. (2019) for recent quantitative assessments of changes in trade barriers on countries' aggregate trade balances.

oretical model that serves as the basis for our analysis. Section 3 describes our data sources and calibration strategy. Section 4 reports the results of our accounting decomposition of bilateral imbalances. Section 5 carries out our counterfactual experiments. Section 6 offers a brief summary and concluding remarks.

2 Model

2.1 Model Setup

2.1.1 Overview

The theoretical foundation of our analysis is a dynamic many-country, many-sector model of international trade. In the model, forward-looking agents make consumption and savings decisions. International asset trade is permitted, and differences in technology and the rate of time preference across countries give rise to aggregate trade surpluses and deficits. Final consumption and investment require tradable inputs from many sectors. Countries differ in their reliance on, and productivity in, these sectors. In addition, sectoral inputs are differentiated by their country of origin. This creates a motive for international trade between and within sectors.

As we will show below, aggregating the sectoral trade flows in this model delivers a compact and intuitive expression for bilateral imbalances. This expression illustrates the role of the three drivers of such imbalances discussed in the Introduction: aggregate trade surpluses and deficits, cross-country differences in production and spending patterns, and asymmetric trade barriers.

We make two crucial assumptions which require some discussion. The first is that agents' lifespans are not infinite, as in the Ramsey model, but may end each period with a constant probability, as in Blanchard (1985). Agents whose life ends are replaced by a cohort of newly-borns. The appearance of new cohorts each period breaks the tight link between the growth rate of aggregate consumption and agents' individual Euler equations which characterises the Ramsey model. As a result, our model permits a non-degenerate distribution of assets in steady state, even in the presence of differences in savings preferences across countries. This, in turn, implies that countries' overall trade need not be balanced in the long run.[6]

The second assumption is that trade within sectors can be characterised by a standard structural gravity equation as in, for example, Anderson (1979) and Anderson and van Wincoop (2003). We obtain this by imposing that countries trade in country-specific sectoral varieties, as in Armington (1969). However, the particular microfoundation of the gravity equation is not crucial for our purposes: we could

[6]In a similar spirit, Matsuyama (1987) uses an open-economy version of the Blanchard model in order to analyse the current-account dynamics of a small open economy whose rate of time preference differs from the world interest rate.

obtain the same gravity equation by letting trade patterns at the sectoral level arise from variants of the Krugman, Chaney-Melitz and Eaton-Kortum models, or even combinations thereof.[7]

2.1.2 Preferences and Endowments

There are many countries, denoted by $n = 1, ..., N$. Time lasts forever, and there is no aggregate uncertainty. However, individual agents face a constant probability of death, ξ, each period. There is a unit mass of agents in each country, and each period an exogenous mass ξ of agents is born in n, so that net population growth is zero in all countries. Agents in country n discount the future at rate ρ_n and are endowed with H_{nt} units of human capital, which they supply inelastically in domestic labour markets at wage w_{nt}. H_{nt} grows exogenously at gross rate γ for all countries: $H_{nt+1} = \gamma H_{nt}$. Agents are born without wealth, but can accumulate it through savings. Actuarially fair life insurance is available: agents in n choose to pay their wealth to the life insurance company if they die, and in return have $1 + \xi / (1 - \xi) = 1 / (1 - \xi)$ times their wealth if they live. There is no bequest motive, and negative bequests are prohibited.

Agents' period utility is logarithmic in final consumption each period, and we denote by $C_{nt}(t')$ the final consumption in period t of an agent in country n who was born in period t'. The optimal-savings problem of an agent born in period t' can be expressed as

$$\max_{\{C_{nt}(t')\}_{t=t'}^{\infty}} \sum_{t=t'}^{\infty} \left(\frac{1-\xi}{1+\rho_n} \right)^{t-t'} \ln C_{nt}(t') \tag{1}$$

subject to

$$P_{nt} C_{nt}(t') + A_{nt+1}(t') = w_{nt} H_{nt} + \frac{R_t}{1-\xi} A_{nt}(t') \tag{2}$$

$$A_{nt'}(t') = 0, \tag{3}$$

where P_{nt} denotes the price of final consumption in country n and period t; R_t is the return to wealth, which is equal across countries (as we discuss below); and $A_{nt}(t')$ is the wealth that a cohort-t' member has at the beginning of period t, before the uncertainty about her death has been resolved.[8] We describe the solution to this problem in Appendix A.1. Aggregate final consumption in country n is a weighted average of the final consumption of cohorts alive in n in period t:

$$C_{nt} = \sum_{t'=-\infty}^{t} \xi (1-\xi)^{t-t'} C_{nt}(t'). \tag{4}$$

[7] See Krugman (1980), Eaton and Kortum (2002), Melitz (2003) and Chaney (2008). The isomorphisms between these models are discussed in detail in Costinot and Rodríguez-Clare (2014).

[8] After this uncertainty is resolved, the wealth of a surviving cohort-t' member in period t is $A_{nt}(t') / (1-\xi)$.

2.1.3 Technologies

In each country n firms assemble a non-traded final good by using inputs from many sectors, $s = 1, ..., S$:

$$X_{nt} = \prod_{s=1} \left(\frac{X_{snt}}{\sigma_{sn}} \right)^{\sigma_{sn}}, \tag{5}$$

where $\sigma_{sn} \in (0,1)$; $\sum_s \sigma_{sn} = 1$; X_{nt} is the output of the final good; and X_{snt} is the quantity of sector-s inputs used. The sector-s input is also non-tradable, but firms assemble it from tradable, country-specific varieties:

$$X_{snt} = \left(\sum_{n'=1}^{N} \omega_{sn'n}^{\frac{1}{1+\theta_s}} x_{sn'nt}^{\frac{\theta_s}{1+\theta_s}} \right)^{\frac{1+\theta_s}{\theta_s}}, \tag{6}$$

where $\theta_s \geq 0$; $\omega_{snn} \geq 0$; and $x_{sn'nt}$ represents the use of the country-n' variety in the production of the sector-s input by country n. The country-n variety in sector s is produced with the Cobb-Douglas technology

$$Q_{snt} = Z_{sn} \left(\frac{K_{snt}^{\alpha_n} H_{snt}^{1-\alpha_n}}{1-\mu_{sn}} \right)^{1-\mu_{sn}} \left(\frac{J_{snt}}{\mu_{sn}} \right)^{\mu_{sn}}, \tag{7}$$

where $\alpha_n, \mu_{sn} \in (0,1)$. K_{snt} and H_{snt} respectively represent the capital and efficiency units of labour used; J_{snt} denotes the use of the country-n final good as intermediate input in s; and shifter Z_{sn} describes the country-sector-specific efficiency of production.

The final good in country n can be used to provide one unit of final consumption, one unit of intermediate input for one of the country-sector-specific varieties, J_{snt}, or $1/\eta_n > 0$ units of investment, I_{nt}: $X_{nt} = C_{nt} + \eta_n I_{nt} + \sum_s J_{snt}$. The parameter η_n thus captures (inversely) the investment efficiency of country n. Investment in country n adds to the country's capital stock according to:

$$K_{nt+1} = I_{nt} + (1-\delta) K_{nt}, \tag{8}$$

where $\delta \in (0,1)$; K_{nt} is the capital stock of n in period t.

2.1.4 Market Structure

Goods and factor markets are perfectly competitive. International trade is subject to iceberg transport costs: $d_{sn'n} \geq 1$ units of the country-n', sector-s variety must be shipped for one unit to arrive in country n. Production factors can move freely between activities within countries, but cannot move across borders.

Agents in all countries can trade in a one-period international riskless bond (which is in zero net supply) in a competitive global bond market. One unit of bond holdings

at the end of period t pays a nominal return of R_t. The wealth that a cohort-t' member has at the beginning of period t is $A_{nt}(t') \equiv K_{nt}(t') + B_{nt}(t')$.

2.2 Steady State

2.2.1 Definition of the Steady State

Throughout the remainder of the paper, we will focus exclusively on steady states of the model described in Section 2.1. For a given set of parameters, the model has a unique steady state in which all aggregate variables – C_{nt}, I_{nt}, K_{nt}, B_{nt} and Y_{nt} – grow at the constant rate γ. Consequently all prices are constant, as are the ratios $C_{nt}/H_{nt} \equiv c_n$, $I_{nt}/H_{nt} \equiv i_n$, $K_{nt}/H_{nt} \equiv k_n$, $B_{nt}/H_{nt} \equiv b_n$ and $Y_{nt}/H_{nt} \equiv y_n$.

The assumption that the world economy is in steady state may seem rather strong. However, as we will show below, it is not crucial for the first part of our analysis in Section 4, in which we provide an account of the sources of the observed variation in bilateral trade imbalances across country pairs. It is only crucial for the second part in Section 5, in which we explore changes in prices, capital stocks and aggregate trade surpluses and deficits in response to counterfactual changes in trade barriers.

We are content to rely on this assumption in Section 5 for two reasons. First, it allows us to perform illustrative counterfactuals about the long-run impact of changes in trade barriers which are in the spirit of typical static trade counterfactuals – but do not require us to assume that capital stocks and trade balances are exogenously given (as in, for example, Deckle et al., 2007; 2008). Second, the calibrated steady state of our model turns out to be consistent with two widely acknowledged observations about aggregate trade balances: i) high-savings countries are more likely to run trade surpluses; and ii) overall trade surpluses and deficits are fairly persistent over time.

2.2.2 Description of the Steady State

Steady-state prices are given by

$$P_n^C = P_n^J = \frac{P_n^I}{\eta_n} = \prod_{s=1}^{S} \left[\sum_{n'=1}^{N} \left(\tau_{sn'n} p_{sn'} \right)^{-\theta_s} \right]^{-\frac{\sigma_{sn}}{\theta_s}} \equiv P_n, \tag{9}$$

where P_{nt}^C, P_{nt}^I and P_{nt}^I respectively denote the final-consumption price, the intermediates price, and the investment price; and

$$p_{sn} = \frac{1}{Z_{sn}} f_n^{1-\mu_{sn}} P_n^{\mu_{sn}}, \quad f_n \equiv \left(\frac{r_n}{\alpha_n} \right)^{\alpha_n} \left(\frac{w_n}{1-\alpha_n} \right)^{1-\alpha_n} \tag{10}$$

where f_n is the factor cost of country n, and $\tau_{sn'n} \equiv \omega_{sn'n}^{-1/\theta_s} d_{sn'n}$. We will refer to $\tau_{sn'n}$ as the sector-s "trade wedge" which applies to imports of country n from n'. As the

model illustrates, we should not think of this wedge as representing trade costs only: $\tau_{sn'n}$ encompasses a trade-cost component, $d_{sn'n}$, as well as a component which derives from countries' preferences/technologies, $\omega_{sn'n}$. Our calibration below will not allow us to identify these components separately. Instead, we will only obtain a measure of the relative magnitude of the overall wedge, $\tau_{sn'n}$. We can think of this wedge as the ad-valorem tax equivalent of all factors which may impede sectoral trade between country pairs.

Equalisation of the returns to physical capital and the riskless bond yields

$$R = \frac{\alpha_n}{\eta_n} \frac{f_n}{P_n} k_n^{\alpha_n - 1} + 1 - \delta. \tag{11}$$

In Appendix A.1 we show that the steady-state ratio of aggregate net exports to GDP of country n is

$$\frac{NX_{nt}}{f_n k_n^{\alpha_n} H_{nt}} = 1 - \frac{\alpha_n \left(1 - \frac{1-\delta}{\gamma}\right)}{\frac{R}{\gamma} - \frac{1-\delta}{\gamma}} - \frac{\xi \left(\rho_n + \xi\right) \frac{R}{\gamma} \left(1 - \alpha_n\right)}{\left[1 + \rho_n - \frac{R}{\gamma}\left(1 - \xi\right)\right] \left[\frac{R}{\gamma} - \left(1 - \xi\right)\right]}. \tag{12}$$

This ratio depends negatively on the capital share of country n (α_n). A country with a large capital share will have a higher share of investment expenditure and a lower share of next exports in GDP, everything else constant. If $\gamma > R$, it also depends negatively on the discount rate of country n (ρ_n). A country with a high discount rate will have negative holdings of the international bond; if $\gamma > R$, the value of new international liabilities it incurs each period outstrips the interest payments it must make on past liabilities in steady state. As a result, its steady-state expenditure exceeds its steady-state GDP, causing a trade deficit. Conversely, a country with a low discount rate will run a trade surplus in steady state.[9]

Applying Shephard's Lemma in equation (9) yields the value of sector-s imports by country n from n':

$$M_{sn'nt} = \frac{\left(\tau_{sn'n} p_{sn'}\right)^{-\theta_s}}{\sum_{n''=1}^{N} \left(\tau_{sn''n} p_{sn''}\right)^{-\theta_s}} \sigma_{sn} \left(\sum_{s=1}^{S} p_{sn} Q_{snt} - NX_{nt}\right). \tag{13}$$

Market clearing implies

$$p_{sn} Q_{snt} = \sum_{n'=1}^{N} M_{snn't}; \quad f_n k_n^{\alpha_n} H_{nt} = \sum_{s=1}^{S} \left(1 - \mu_{sn}\right) p_{sn} Q_{snt}; \quad \sum_{n=1}^{N} NX_{nt} = 0. \tag{14}$$

[9]In our calibration below, $\gamma > R$ turns out to be the relevant case. If $\gamma < R$, the interest payments an impatient country makes in steady state outstrip its new international liabilities. In this case, the country's steady-state GDP exceeds expenditure, causing a trade surplus. Conversely, a patient countries will run a trade deficit in steady state.

For given model parameters, there is a unique (up to a normalisation) vector of equilibrium factor costs, $\{f_n\}_n$, which satisfies pricing conditions (9) and (10) and market-clearing conditions (13) and (14).

Finally, we can express the steady-state real GDP per effective worker of country n as

$$\frac{Y_{nt}}{H_{nt}} \equiv \frac{f_n}{P_n} k_n^{\alpha_n} = k_n^{\alpha_n} \times \prod_{s=1}^{S} \left(\frac{Z_{sn}}{\tau_{snn}} \right)^{\frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}} \times \prod_{s=1}^{S} \left(\frac{M_{snnt}}{\sum_{n'=1}^{N} M_{sn'nt}} \right)^{-\frac{1}{\theta_s}\frac{\sigma_{sn}}{1-\sum_s \sigma_{sn}\mu_{sn}}} . \tag{15}$$

Note that real GDP is the product of three terms, respectively: the per-effective worker capital stock (which is endogenous); a weighted geometric average of sectoral productivities relative to internal trade barriers (which we will take as exogenous); and a weighted geometric average of ACR terms which capture the contribution of trade to income (and which are endogenous).[10]

2.3 Bilateral Trade Imbalances

2.3.1 A Gravity Representation of Bilateral Trade Balances

For our analysis of the drivers of bilateral trade balances, it is convenient to write the expression for the trade balance between countries n and n' in "gravity form". From equation (13),

$$M_{n'nt} - M_{nn't} = \frac{p_{n'}Q_{n't}\left(p_n Q_{nt} - NX_{nt}\right)}{\sum_n p_n Q_{nt}} \sum_{s=1}^{S} \left(\frac{\tau_{sn'n}}{O_{sn'} P_{sn}} \right)^{-\theta_s} q_{sn'}\sigma_{sn} +$$

$$-\frac{p_n Q_{nt}\left(p_{n'}Q_{n't} - NX_{n't}\right)}{\sum_n p_n Q_{nt}} \sum_{s} \left(\frac{\tau_{snn'}}{O_{sn} P_{sn'}} \right)^{-\theta_s} q_{sn}\sigma_{sn'}, \tag{16}$$

where $M_{n'n} \equiv \sum_s M_{sn'n}$ is the total value of imports by country n from n'; $p_n Q_{nt} \equiv \sum_s p_{sn} Q_{snt}$ is the total value of country-n total output; $q_{sn} \equiv p_{sn} Q_{snt} / \left(p_n Q_{nt}\right)$ is the share of country-n output in sector s; and

$$O_{sn'} \equiv \left[\sum_n \left(\frac{\tau_{sn'n}}{P_{sn}} \right)^{-\theta_s} \sigma_{sn} \frac{p_n Q_{nt} - NX_{nt}}{\sum_n p_n Q_{nt}} \right]^{-\frac{1}{\theta_s}} \tag{17}$$

is the so-called "outward multilateral resistance term" of country n' in s. Correspondingly, P_{sn} is sometimes referred to as the "inward multilateral resistance term" of country n in s, and it can be re-written as:

$$P_{sn} = \left[\sum_{n'} \left(\frac{\tau_{sn'n}}{O_{sn'}} \right)^{-\theta_s} q_{sn'} \frac{p_{n'}Q_{n'}}{\sum_n p_n Q_n} \right]^{-\frac{1}{\theta_s}} . \tag{18}$$

[10]See Arkolakis et al. (2012), Costinot and Rodríguez-Clare (2014) and Ossa (2015).

Equations (16)-(18) illustrate how bilateral trade imbalances are shaped by aggregate trade surpluses and deficits, cross-country differences in production and spending patterns, and asymmetric trade barriers. Everything else constant, the trade deficit of country n with n' will be larger,...

1. ...the larger the aggregate trade deficit of n; and the larger the aggregate trade surplus of n'.

2. ...the larger the share of spending by n in sectors which account for a large share of production in n'; and the smaller the share of spending by n' in sectors which account for a large share of production in n.

3. ...the smaller the trade wedges for shipping from n' to n relative to all trading opportunities of country n; and the larger the trade wedges for shipping from n to n' relative to all trading opportunities of country n'.[11]

Moreover, the equations show that if all trade were balanced in the aggregate ($NX_{nt} = 0$ for all n), if production and spending shares were the same across countries ($q_{sn} = \sigma_{sn} = q_s = \sigma_s$ for all n), and if trade wedges were symmetric ($\tau_{sn'n} = \tau_{snn'}$ for all n and n'), all trade would be balanced bilaterally. This is because $P_{sn} = O_{sn}$ for all n in this case.

2.3.2 Linear Approximation

In Appendix A.2 we show that equation (16) can be linearly approximated by means of a first-order Taylor expansion as:

$$\frac{M_{n'nt} - M_{nn't}}{M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}}} \simeq \Omega \sum_s \left(\frac{M_{sn'nt} M_{snn't}}{M_{n'nt} M_{nn't}} \right)^{\frac{1}{2}} \left\{ \ln \left(\frac{1 - NX_{nt}/p_n Q_{nt}}{1 - NX_{n'}/p_{n'} Q_{n't}} \right) + \right. \tag{19}$$

$$\left. + \ln \left(\frac{q_{sn'} \sigma_{sn}}{q_{sn} \sigma_{sn'}} \right) - \theta_s \ln \left(\frac{\tau_{sn'n}}{\tau_{snn'}} \right) - \theta_s \ln \left(\frac{O_{sn} P_{sn'}}{O_{sn'} P_{sn}} \right) \right\},$$

where $\Omega > 0$ is an arbitrary constant.

The expression in (19) tells us that − to a first-order approximation − we can decompose the bilateral trade balance between countries n and n' into four additive terms: one representing differences in the countries' overall trade surpluses; one representing differences in the countries production and spending patterns; one representing bilateral asymmetries in trade wedges; and one representing differences in the countries ratios of outward to inward multilateral resistance terms (MRTs hereafter). It follows from the discussion in Section 2.3.1 that deviations from zero of

[11] Equation (16) corresponds to equation (6) in Davis and Weinstein (2002) − up to the terms in round brackets containing the sectoral trade wedges and multilateral resistance terms. In taking this equation to the data, Davis and Weinstein (2002) control for trade barriers by means of standard "gravity" proxies for trade costs, but they omit theory-consistent multilateral resistances.

the last term must be the result of deviations from zero across the other three terms for countries n and n' with at least some of their trading partners. Therefore, we can loosely think of the final term as arising from the "interaction" of overall trade positions, differences in production and spending patterns and asymmetric wedges across the trade partners of n and n'.

Throughout the remainder of the paper, when we refer to "bilateral (trade) imbalances", we will be referring to the left-hand size of equation (19): the difference in the bilateral trade flows between countries n and n', divided by the geometric average of their trade flows. This is approximately equal to the *log difference* between the bilateral flows. By contrast, Davis and Weinstein (2002) analyse the variance of the simple difference in bilateral trade flows. Since

$$M_{n'nt} - M_{nn't} = \frac{M_{n'nt} - M_{nn't}}{M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}}} M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}} \simeq \left(\ln M_{n'nt} - \ln M_{nn't}\right) M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}}, \quad (20)$$

their trade imbalances are equivalent to ours multiplied by the geometric average of countries' bilateral flows. We focus on the log difference for two reasons. First, the simple difference gives outsized weight to pairs of large countries: a 1% US-China imbalance will show up as much larger than a 1% Spain-Germany imbalance. Second, as equation (20) shows, the simple difference conflates the issue of how well the standard structural gravity equation can explain variation in the average value of trade flows across country pairs with the issue of how well it can explain variation in the percentage difference between bilateral flows. Since we already know that the gravity equation performs very well with respect to the former, it seems appropriate to isolate the latter issue.[12]

In the next section, we will calibrate the steady state of our model to match observed bilateral trade flows, aggregate trade surpluses and sectoral production and spending patterns perfectly. In Section 4, we will then perform a decomposition of the variance of bilateral imbalances using equation (19). Note that this decomposition does not rely on the assumption that the world economy is in steady state. It can be performed for given observed trade flows, aggregate surpluses and sectoral shares irrespective of the "fundamentals" of the world economy which give rise to them. The only crucial assumption to arrive at (19) is that, within periods, sectoral trade flows can be modelled using the gravity-consistent expression in (13).

[12]We provide some further discussion of the implications of normalising trade balances by $M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}}$ in Appendix A.

3 Data and Calibration

3.1 Data

Our analysis relies on data from two main sources: the Penn World Tables (PWT 9.0; Feenstra et al., 2015), and the World Input Output Database (WIOD 2016 release; Timmer et al., 2015). For all data taken from these sources, we calculate a simple five-year average of the reported values in our period of interest. We do this so as to average out short-run fluctuations in the values of trade balances, incomes and expenditure shares. Our baseline analysis uses data for the five most recent years available, 2010-14.

The 2016 release of WIOD consists of annual global input-output tables covering 43 countries and the “rest of the world”, with spending broken down into 56 sectors at the 2-digit level of ISIC (Rev. 4). Out of the 43 countries, three have populations of less than 1 million (Cyprus, Luxembourg and Malta). We merge these with the “rest of the world” totals to focus on larger and more diversified economies. We also aggregate sectors to obtain 16 broad manufacturing sectors and 15 service sectors. We do this in order to make the data consistent with available information on sectoral trade elasticities (see below). The resulting global input-output table covers 40 countries and the “rest of the world”, with spending broken down into 31 sectors. Tables A1-A3 in the Appendix give an overview of our aggregation of regions and sectors relative to the original WIOD data. To construct “rest of the world” data from the PWT, we aggregate factor endowments, incomes and income shares for all countries included in PWT but not among the 40 individual countries covered in our final world input-output table.

[Insert Table 1 here]

From the WIOD data, we obtain the value of country-n spending on country-n' output in sector s, $\{M_{sn'nt}\}_{s,n',n}$.[13] Summing across sectors, yields $(41 \times 40/2 =)$ 820 distinct bilateral trade balances. Table 1 presents summary statistics for the absolute value of these, expressed relative to the geometric average of the two bilateral flows: $|M_{n'nt} - M_{nn't}| \,/\, \left(M_{n'nt}^{1/2} M_{nn't}^{1/2}\right)$. The median is equal to .46, and there is significant variation: the smallest imbalance is (nearly) 0, while the largest ratio is 5.01.

[13] For our country sample, and our chosen level of sectoral aggregation, zero-valued flows are very uncommon. Out of a total of $(31 \times 41 \times 41 =)$ 52,111 sector-country-pair flows, less than 2% are zero-valued.

3.2 Calibration

3.2.1 Production, Population and Preference Parameters

Some model parameters can be taken directly from PWT and WIOD data. We calculate capital shares, $\{\alpha_n\}_n$, as 1 minus a country's labour share reported in PWT 9.0. The share of total country-n spending on sector-s, $\{\sigma_{sn}\}_{s,n}$, and the share of country-n spending on intermediates in sector s, $\{\mu_{sn}\}_{s,n}$, are computed based on the information contained in WIOD.

To obtain investment efficiencies, $\{\eta_n\}_n$, we use equation (11) to match the per-effective-worker capital stocks, $\{k_n\}_n$, in PWT 9.0 for a given world interest rate. The target world interest rate in our baseline calibration is $R = 1.030$ based on estimates by King and Low (2014) of the real world interest rate during the 1985-2014 period. Our sectoral trade elasticities, $\{\theta_s\}$, are taken from Caliendo and Parro (2015) and Costinot and Rodríguez-Clare (2014). The value of these elasticities is reported in Table A3. The capital depreciation rate is calibrated to be $\delta = .06$.

We set the steady state growth rate to $\gamma = 1.044$ to match the average annual growth rate of world GDP during the 1985-2014 period from PWT 9.0. Note that this implies $\gamma > R$. The probability of death for an individual agent is put at $\xi = .13$, yielding an expected lifespan of 60 years for an agent in our model.

Finally, we use the discount rates, $\{\rho_n\}_n$, to match observed trade balances. The value of the trade balance as a share of country-n GDP, $\{NX_{nt}/\left(f_n k_n^{\alpha_n} H_{nt}\right)\}_n$, is taken from WIOD, which provides consistent values of countries' aggregate trade surpluses. The resulting correlation between discount rates and aggregate trade balances is -.75: more impatient countries tend to have trade deficits, while patient countries tend to have surpluses.

3.2.2 Productivity and Trade-Cost Parameters

The WIOD data gives us $SN\left(N-1\right)$ sectoral spending shares. To match these, our model allows us to choose $SN\left(N-1\right)$ relative trade wedges, and $S\left(N-1\right)$ relative sectoral productivities. This leaves us with $S\left(N-1\right)$ degrees of freedom in calibrating productivity and trade-cost parameters. We follow Eaton and Kortum (2002) and exploit these degrees of freedom to attribute to trade wedges only the residual portion of trade shares which cannot be attributed to country-sector variation.[14]

Specifically, we use equation (13) to derive:

$$\frac{M_{sn'nt}}{M_{snnt}^{\frac{1}{2}} M_{sn'n't}^{\frac{1}{2}}} = \left[\frac{q_{sn'}\sigma_{sn}\left(1-nx_n\right)}{q_{sn}\sigma_{sn'}\left(1-nx_{n'}\right)}\left(\frac{O_{sn}}{O_{sn'}}\frac{P_{sn'}}{P_{sn}}\right)^{-\theta_s}\right]^{\frac{1}{2}}\left(\frac{\tau_{sn'n}}{\tau_{snn}^{\frac{1}{2}}\tau_{sn'n'}^{\frac{1}{2}}}\right)^{-\theta_s}. \tag{21}$$

[14]See Eaton and Kortum (2002), Section 5.1, pp. 1759-1762.

We then estimate the gravity equation

$$\frac{M_{sn'nt}}{M_{snnt}^{\frac{1}{2}} M_{sn'n't}^{\frac{1}{2}}} = \exp\left\{\Delta_{sn'} - \Delta_{sn} + \varepsilon_{sn'n}\right\}, \tag{22}$$

where Δ_{sn} is a sector-country fixed effect, and $\varepsilon_{sn'n}$ is an error term. Finally, we impose

$$\left(\frac{\tau_{sn'n}}{\tau_{snn}^{\frac{1}{2}} \tau_{sn'n'}^{\frac{1}{2}}}\right)^{-\theta_s} = \exp\left\{\hat{\varepsilon}_{sn'n}\right\} \quad \forall\, n', n, \tag{23}$$

and we choose $\{Z_{sn}/Z_{sUSA}\}_{s,n\neq USA}$ so as to match $\Delta_{sn'} - \Delta_{sn}$. The additional restriction in (23) amounts to minimising the role played by trade wedges in explaining sectoral trade patterns.

[Insert Table 2 here]

This leaves us with S absolute sectoral productivities for our reference country, the U.S., and SN "internal" trade wedges, $\{\tau_{snn}\}_{s,n}$. We would like our model to match the per-effective-worker GDPs of our sample countries which, from equation (15), imposes a further N restrictions on these $S\,(N+1)$ parameters. Beyond these, however, there is no need to pin down parameters further as all productivities and internal trade wedges will remain constant throughout our analysis, and their absolute values have no bearing on any of the results presented below. Table 2 presents an overview of our model calibration.

4 Bilateral Balance Accounting

4.1 Variance Decomposition

We begin by decomposing the variation in bilateral imbalances across country pairs using equation (19). Note that the calibration of productivities and trade wedges described in Section 3.2.2 implies that

$$-\theta_s \ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right) = \hat{\varepsilon}_{sn'n} - \hat{\varepsilon}_{snn'}$$

$$-\theta_s \ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right) = 2\left(\hat{\Delta}_{sn'} - \hat{\Delta}_{sn}\right)\frac{q_{sn}\sigma_{sn'}\left(1 - NX_{n't}/p_{n'}Q_{n't}\right)}{q_{sn'}\sigma_{sn}\left(1 - NX_{nt}/p_{n}Q_{nt}\right)}.$$

Under the parameter restrictions described in Section 3.2.2, we thus obtain the third and fourth terms of expression (19) directly from the country-sector dummies estimated using (22). Moreover, we do not need to take a stance on sectoral trade elasticities to proceed with the decomposition.

Figure 3 plots the approximated country-pair trade imbalances against their data counterparts. As the figure shows, the correlation between the two is high: the R^2 with respect to the 45-degree line is .90, and there are only a handful significant outliers. This strongly suggests that we can meaningfully decompose bilateral imbalances for the large majority of country pairs using the approximation in equation (19).

[Insert Figure 3 here]

In Figure 4, we plot each of the four terms in (19) against the respective (approximated) country-pair trade imbalance. In each panel, the red line represents the line of best fit. The slope of this line, also shown in red, corresponds to the share of the variation in trade imbalances which can be attributed to each term.[15] By construction, the four slope coefficients add up to 1.

[Insert Figure 4 here]

As can be seen from Figure 4, variation in countries' aggregate trade balances accounts for the smallest share of the variation in bilateral trade imbalances – a mere 2%. Differences in production and spending patterns ("triangular trade") account for 12% of the variation, and asymmetric trade wedges account for 38%. The remaining 47% are due to variation in the ratio of inward to outward MRTs. As discussed in Section 2.3.2, we can think of this last term as reflecting the result of interactions between the first three.

There are three main takeaways from our variance decomposition. First, overall trade surpluses and deficits explain only a vanishingly small portion of the variation in bilateral imbalances across country pairs. This is striking because macroeconomic imbalances are frequently cited as a key driver of bilateral imbalances in the public discourse. Our results suggest that this emphasis may be misplaced. Second, differences in the gap between the outward and inward MRT across countries are an important factor behind the variation in bilateral imbalances. This finding is noteworthy because the original analysis of bilateral trade balances by Davis and Weinstein (2002), which pre-dated the structural gravity "revolution", did not account for the role of MRTs at all.

Third and finally, we re-cover the "mystery" uncovered by Davis and Weinstein (2002) in a different guise: large asymmetries in trade wedges are required to explain why some country pairs have bigger imbalances than others. Since we calibrate these wedges as a gravity residual, we can think of the resulting trade-wedge asymmetries as reflecting the portion of bilateral imbalances we cannot account for through observables (such as aggregate trade balances or production and spending shares). This portion amounts to 38%. Indeed, this number represents a likely understatement

[15] To see this, note that the slope of a univariate linear regression of x_i on y is $Cov\left(x_i, y\right)/Var\left(y\right)$; and that for $y \equiv \sum_i x_i$, we can write $Var\left(y\right) = \sum_i Cov\left(x_i, y\right)$.

since equations (17) and (18) tell us that asymmetries in trade wedges also contribute to (variation in) the gap of between outward and inward MRTs. We return to this point in Section 5.

In Appendix A.3, we repeat our variance decomposition for data from the 1995-1999 period, the earliest for which WIOD data is available. The quantitative results for this earlier period are virtually the same as those described above. We also show that there is a strong correlation between 2010-2014 bilateral trade balances and their 1995-99 counterparts, even 15 years on.

4.2 Trade-Wedge Asymmetries

Having shown that trade-wedge asymmetries are required to account for a large share of the variation in bilateral trade imbalances, we now investigate their properties further. Define the log difference between "average" trade wedges from country n' to n and "average" wedges from country n to n' as

$$\ln \tau_{n'n} - \ln \tau_{nn'} \equiv \sum_s \left(\frac{M_{sn'nt} M_{snn't}}{M_{n'nt} M_{nn't}} \right)^{\frac{1}{2}} \frac{\theta_s}{\theta} \left(\ln \tau_{sn'n} - \ln \tau_{snn'} \right) =$$

$$= \sum_s \left(\frac{M_{sn'nt} M_{snn't}}{M_{n'nt} M_{nn't}} \right)^{\frac{1}{2}} \frac{\hat{\varepsilon}_{snn'} - \hat{\varepsilon}_{sn'n}}{\theta}. \tag{24}$$

where θ is the aggregate trade elasticity.

The larger is $\ln \tau_{n'n} - \ln \tau_{nn'}$, the more difficult it is to sell goods and services from n' in n relative to selling goods and services from n in n'.

[Insert Table 3 here]

Table 3 reports summary statistics for the absolute value of $\ln \tau_{n'n} - \ln \tau_{nn'}$ across our 820 distinct country pairs, imposing $\theta = 4$. We choose $\theta = 4$ throughout, in keeping with Simonovska and Waugh's (2014) estimate of the aggregate trade elasticity, and because it is close to the median of our sectoral trade elasticities in Table A3 (which is 5). The table highlights that sizeable trade-wedge asymmetries are required for the model to fit sectoral trade flows perfectly. For the median country pair, the average import wedge in one direction is roughly 6% higher than in the other direction. For 10% of country pairs, this gap is larger than 50%.

[Insert Figure 5 here]

By way of illustration, Figure 5 displays the log difference between the U.S. average import wedge from each of its trading partners and the corresponding partner's average import wedge from the U.S. As can be seen from the figure, the U.S. has lower import wedges for roughly half its trade partners relative to the wedges which

apply to U.S. imports in the partner country. In some cases, these differences are not small: the calibration implies that import wedges from the U.S. to Mexico are almost 18% larger than import wedges from Mexico to the U.S. However, not every large US bilateral deficit is associated with low U.S. import wedges relative to the respective trade partner's. For example, the U.S. has its largest bilateral trade deficit with China. Yet Chinese imports into the U.S. actually face a 3% higher trade wedge than U.S. imports into China.

The pattern in Figure 5 is fairly typical across countries. Most countries in our sample have a roughly even number of trade relationships in which their average import wedge is lower than the partner's wedge in the other direction, and of those in which it is higher. The country with the largest number of negative bilateral trade-wedge gaps (China) has 26, the country with the smallest number (Greece) has 11. The standard deviation of bilateral trade-wedge gaps across countries ranges from .06 to .18.

[Insert Table 4 here]

In order to ascertain whether the asymmetries in trade wedges appear to be systematically related to observable characteristics of country pairs, we regress them on a range of standard gravity variables for all pairs (except the 40 pairs involving the rest of the world). The results are displayed in Table 4. Columns 1-3 successively introduce some commonly used variables in the empirical analysis of bilateral trade flows: the log of population-weighted distance between countries n' and n (see Head and Mayer, 2014); a "contiguous" dummy which takes value 1 if n' and n share a common border, 0 otherwise; a "colonial" dummy which takes value 1 if n' and n share a colonial history, 0 otherwise; a "common currency" dummy which takes value 1 if n' and n share a currency, 0 otherwise; an FTA dummy which takes value 1 if n' and n are parties to a free-trade agreement, 0 otherwise; and an EU dummy which takes value 1 if n' and n are both EU members, 0 otherwise. In addition, the specification in column 4 employs a full set of country fixed effects.

The trade-wedge asymmetries implied by our calibration do not correlate strongly with any of these gravity variables: the estimated coefficients are small and not robustly statistically significant. While the conditional correlations in Table 4 cannot provide conclusive proof either way, the patterns do not lend much support to the notion that the trade-wedge asymmetries implied by our model calibration are systematically related to geography, trade agreements or the institutional environment of countries' trade relationships.

5 Counterfactuals

5.1 Trade-Cost Counterfactuals in the Model

The variance decomposition in Section 4 allows us to make an informative first assessment of the relative importance of aggregate trade balances, differences in sectoral spending and production shares and trade-wedge asymmetries in accounting for observed differences in bilateral imbalances. However, a static decomposition of this type has two shortcomings.

First, as shown in Section 4.1, a large part of the variation is attributed to variation in the ratio of inward to outward MRTs across countries – which reflects the interaction of the three main channels. If, for example, all trade wedges were symmetric across countries, we know that the ratio of the inward to outward MRTs would tend to be closer to 1 for all countries. This would diminish the importance of the fourth term in expression (19).

Second, changes in the world economy which significantly affect consumption and saving, sectoral spending and production, and trade wedges would be expected to have general-equilibrium effects – not only on prices, but also on the magnitude and distribution of per-effective-worker capital stocks and overall trade surpluses and deficits. For example, a change in trade costs which makes all trade wedges bilaterally symmetric may raise the marginal product of capital in some countries relative to others. The result would be a change in the distribution of capital across countries, in the world interest rate, and in the magnitude of steady-state aggregate trade balances.

These shortcomings can only be addressed through a fully-fledged counterfactual. In the following, we will use the model developed in Section 2 to provide two counterfactuals with respect to changes in trade barriers. The first is more stylised, and intended to complement the variance decomposition in Section 4. The underlying thought experiment is: what would bilateral imbalances look like in a world in which trade policy has made trade wedges bilaterally symmetric? We focus on trade-wedge asymmetries because Section 4 has shown them to be the most important individual driver of differences in bilateral trade balances across countries. The second counterfactual is more concrete, and considers the impact of a recent real-world change in trade costs: the rise in tariffs as a result of the U.S.-China trade war since January 2018.

5.2 Global Trade-Wedge Symmetry

The trade-wedge parameters defined in Section $\{\tau_{sn'n}\}_{s,n',n}$, capture the ad-valorem tax equivalent of all impediments to trade between two countries in a given sector. Both our counterfactuals will consider increases in the iceberg component of these

wedges. For the first, we simply impose

$$d_{sn'n}^{new} = d_{sn'n} \times \max\left\{\frac{\tau_{snn'}}{\tau_{sn'n}}, 1\right\} \quad \forall\, s, n', n \neq n'. \tag{25}$$

In each sector s, the iceberg import cost of the country with the lower import wedge rises to equalise it with the trade partner's higher wedge. One way to think of this experiment is as a revenue-free trade policy which aims to equalise trade wedges in order to create bilaterally "fair" trading conditions.

Figure 6 plots the remaining bilateral imbalances in the counterfactual new steady state of the world economy against the original (actual) imbalances. In the counterfactual steady state, there is a lot less variation in bilateral imbalances: the slope of the line of best fit between the new and the original bilateral imbalances is only .42. In line with the discussion in Section 4.1, it suggests that asymmetric trade wedges account (approximately) for 60% of the variation in bilateral imbalances, once their MRT and general-equilibrium effects are taken into account.

[Insert Figure 6 here]

Most of the indirect effects of imposing symmetric wedges on bilateral trade balances are the result of changes in the MRTs. Analogously with (24), we define

$$\ln\left(\frac{O_n}{P_n}\right) \equiv \sum_{n'}\sum_{s}\left(\frac{M_{sn'nt}M_{snn't}}{M_{n'nt}M_{nn't}}\right)^{\frac{1}{2}}\frac{\theta_s}{\theta}\left[\ln\left(\frac{O_{sn}}{P_{sn}}\right) - \ln\left(\frac{O_{sn'}}{P_{sn'}}\right)\right] \tag{26}$$

as the average gap of the outward to inward MRT in country n, relative to all its trade partners. Figure 7 shows values of this statistic for all countries in our data in the original and counterfactual steady state (light blue and navy bars, respectively). The figure illustrates a dramatic decline in the variance of the average outward-inward-MRT gap across countries, from .012 to .004. Unsurprisingly, some of the largest changes are experienced by smaller countries which are more strongly affected by changes in their external trade wedges.

[Insert Figure 7 here]

Meanwhile, the rise in trade barriers has almost no impact on overall trade deficits and surpluses. Figure 8 presents countries' overall trade deficits, as a percentage of GDP, in the original and new steady state (light blue and navy bars, respectively). The changes are virtually imperceptible. This is because the new set of trade barriers leaves the world interest rate almost unchanged. The higher trade barriers increase the investment price index in all countries, which reduces the global demand for capital. It also reduces the world economy's efficiency in adding to capital stocks, which reduces the global supply of capital. The net effect of these countervailing

forces on the world interest rate is nearly zero, and without changes in the world interest rate – via equation (12) –there are no changes in aggregate trade balances.

[Insert Figure 8 here]

Absent asymmetries in trade wedges, bilateral imbalances in the new steady state are entirely the result of aggregate trade balances, and differences in production and spending patterns. In Figure 9, we perform the variance decomposition described in Section 4.1 using the new data generated by our counterfactual steady state. By construction, the contribution of trade-wedge asymmetries to the variation in bilateral imbalances in now zero. Moreover, the individual contribution of overall trade surpluses and deficits remains small, at just over 4%. Therefore, most of the remaining variation in the MRT term – and, hence, most of the remaining variation in bilateral imbalances – must be due to "triangular trade". This observation gives rise to one of the headline findings of our analysis: more than half of the variation in bilateral imbalances must be attributed to asymmetric trade wedges, while overall trade surpluses and deficits account for a negligible share; the rest is due to differences in the production and spending patterns of countries.

[Insert Figure 9 here]

By raising trade barriers, our counterfactual reduces the real GDP of all countries. Figure 10 gives an overview of the declines in real GDP and aggregate consumption per effective worker in the new steady state relative to the status quo. Aggregate consumption in all countries is proportional to real GDP, with a factor of proportionality that depends only on parameters and the world interest rate:

$$c_n = \frac{\gamma\xi\left(\rho_n + \xi\right)R\left(1-\alpha_n\right)}{\left[\gamma\left(1+\rho_n\right) - R\left(1-\xi\right)\right]\left[R - \gamma\left(1-\xi\right)\right]} y_n. \tag{27}$$

Since the world interest rate changes little between the original and the new steady state, the declines in consumption closely track the declines in countries' GDPs. As would be expected, smaller countries generally see larger declines in real consumption and GDP. However, even for larger countries, the bilateral equalisation of trade wedges has substantive effects: for Japan and the U.S. real GDP falls by 2.6% and 2.7%, respectively; for Germany and China, by 4.8% and 5.2%, respectively.

[Insert Figure 10 here]

So as to return to our motivating example, Figure 11 contrasts U.S. bilateral net exports (as a percentage of U.S. GDP) in the counterfactual steady state with their contemporary counterparts. Trade-wedge symmetry causes some of large bilateral deficits to shrink – notably, the U.S. deficit with China, Mexico and Canada. However, it also causes some deficits to rise – notably those with Japan, Germany and

Korea – and some surpluses to turn into deficits – notably, those with Ireland, the Netherlands and France. This "reshuffling" of imbalances is easy to explain: since we know from Figure 8 that the overall U.S. trade deficit is barely affected by the changes in trade barriers, any reduction in a bilateral deficit must be offset by an increased deficit or reduced surplus with another trade partner.

[Insert Figure 11 here]

Note that, in line with the discussion in Section 2.3.2, we can re-write U.S. bilateral net exports towards trade partner n as

$$\frac{M_{USA,nt} - M_{n,USA,t}}{P_{USA}Y_{USA,t}} = \frac{M^{\frac{1}{2}}_{USA,nt}M^{\frac{1}{2}}_{n,USA,t}}{P_{USA}Y_{USA,t}} \frac{M_{USA,nt} - M_{n,USA,t}}{M^{\frac{1}{2}}_{USA,nt}M^{\frac{1}{2}}_{n,USA,t}}, \tag{28}$$

where the first term is the average value of U.S. bilateral trade with country n; and the second term is what we have been referring to as the U.S. imbalance with country n. The changes in Figure 10 represent the interaction of changes in both these terms. Figure 11 separates them out: Panel A displays changes in U.S. average trade values with its trading partners; Panel B changes in the "imbalance" term.

[Insert Figure 12 here]

Since our counterfactual raises trade barriers everywhere, it is unsurprising that Panel A shows the value of all trade flows relative to U.S. GDP shrink. Meanwhile, Panel B illustrates that the distribution of (proportional) U.S. imbalances narrows: the variance declines from .282 to .147. This contributes to the rise in U.S. net exports towards China, Mexico and Canada observed in Figure 11. Yet it is also behind the rise in the U.S. deficit with Japan, Germany and Korea observed there.

Furthermore, Panel B of Figure 12 highlights the importance of the changes in MRTs which result from equalising trade wedges bilaterally. For example, the figure shows that the U.S. imbalance with China declines, *despite* the fact that Figure 5 showed that U.S. import wedges from China were actually *higher* in the original steady state than Chinese wedges from the U.S. Without MRT changes, we would have expected the U.S.-China imbalance to grow, not shrink. However, as can be seen from Figure 7, China has a relatively high outward MRT in the baseline steady state: the calibration identifies China as a country with generally relatively good exporting opportunities relative to its importing opportunities. This makes China more prone to being a net exporter in bilateral trade relationships. From Figure 7, our trade-cost counterfactual rebalances exporting and importing opportunities for China towards importing – and this causes the U.S.-China imbalance to shrink.

5.3 U.S.-China Trade War

In the second counterfactual, we let U.S.-China trade wedges rise to simulate the effect of the tariffs imposed by the U.S. on China between January 2018 and June 2019, and the retaliatory tariffs imposed by China during this period. Between January 2018 and June 2019, the U.S. increased average tariffs on Chinese imports under Section 301 of the U.S. Trade Act by 14.4 percentage points. In retaliation, China increased average tariffs on U.S. imports by 13.5 percentage points.[16] In Appendix A.4, we describe how we compute sectoral-level tariff changes on U.S.-China trade consistent with our sectoral aggregation, and we show how these tariffs affect U.S.-China trade wedges in Table A4. Our counterfactual should be interpreted as the new long-run steady state of the world economy if the new tariffs imposed between the U.S. and China up until June 2019 remain in place permanently, and everything else is constant.

[Insert Figure 13 here]

As in Section 5.2, the rise in trade barriers has a very limited effect on the world interest rate. Therefore, as before, countries' overall trade balances remain virtually unchanged. Figure 13 gives an overview of the long-run impact of the tariffs on U.S. bilateral net exports. The U.S.-China deficit is halved in the new steady state. This is the result of two effects. The new tariffs reduce the average value of bilateral trade flows between the U.S. and China relative to U.S. GDP. Moreover, since U.S. tariffs are somewhat higher than Chinese tariffs, they reduce the proportional trade imbalance between the two economies.[17] Therefore, the counterfactual suggests that the trade war may − in the long run − achieve President Trump's goal of reducing the U.S.-China deficit.

[Insert Figure 14 here]

However, the model also shows this to be a Pyrrhic victory for two reasons. First, with the U.S. overall trade balance unchanged, U.S. net exports to every other trade partner deteriorate. This is especially stark vis-à-vis the rest of the world, where the trade war turns the largest U.S. bilateral surplus into a deficit. The second reason can be seen in Figure 14: the U.S. and China both lose equally from the trade war, with steady-state reductions in real GDP and consumption of around a fifth of a percent.[18] Third-country effects are generally small, with one notable exception: as U.S. imports are diverted to Mexico, the latter gains an additional .15% of GDP in the long run.

[16] See Bown et al. (2019) and Bown (2019).

[17] See Appendix A4 for more details.

[18] Note that we continue to abstract from tariff revenue, as we are primarily interested in the impact of the trade war on trade imbalances, not welfare.

6 Conclusion

We use a dynamic quantitative trade model to match the observed aggregate trade balances, sectoral expenditure and production shares, and sector-level bilateral trade flows of 40 economies (and the rest of the world) in the 2010-14 period. Through a static variance decomposition and fully-fledged counterfactuals, we show that a large share of the variation in bilateral imbalances is the result of observed differences in country's aggregate trade balances, spending patterns and industrial structure. However, over half of the variation cannot be accounted for without resorting to not directly observable, "residual" asymmetries in trade wedges. If we interpret these wedges as reflecting trade costs, the removal of the asymmetries implied by our calibration would have a significant effect on international trade patterns and welfare.

Three aspects of our findings are noteworthy. First, bilateral trade imbalances regularly fuel political controversies between observers who regard them as a symptom of unfair trade practices (which our calibration would capture as asymmetric trade wedges) and observers who see them as a mere reflection of countries' macroeconomic conditions (which our calibration would capture as differences in aggregate trade balances). Our findings suggest that, in fact, more than a third of the variation in bilateral trade balances is due to well-documented differences in countries' expenditures and industrial structures. This mundane, yet important explanation of bilateral imbalances receives disproportionally little attention in the public discourse.

Second, the quantitatively significant role of asymmetric trade wedges raises the question what exactly these asymmetries capture. Our first-pass analysis does not yield any evidence that they are systematically related to geography, trade agreements or the institutional environment of countries' trade relationships. This, together with the fact that wedges are obtained as a residual in our calibration, suggests that they simply reflect an aspect of trade patterns our model or data are not rich enough to explain. Since our work suggests that this aspect is significant from a positive and welfare standpoint, unpacking trade-wedge asymmetries emerges as an important objective for future research.

Third, whatever the origins of asymmetric trade wedges, our counterfactuals imply that they have very little impact on aggregate trade surpluses and deficits. In our model, the aggregate trade balance is primarily determined by macroeconomic factors – such as country's savings preferences and the world interest rate – upon which trade policy only has a second-order effect. Therefore, a country which reduces a specific bilateral trade deficit by raising import barriers on the respective trade partner, in addition to lowering consumer welfare, is only likely to see its deficits with other trade partners grow.

$\lvert M_{n'nt} - M_{nn't} \rvert / \left(M_{n'nt}^{1/2} M_{nn't}^{1/2} \right)$					
# obs.	mean	st. dev.	10th pctl.	median	90th pctl.
820	.645	.620	.081	.463	1.441

Table 1: Bilateral trade imbalances: 40 countries and Rest of the World

$M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 individual economies and the rest of the world.

Object	Data
ξ	$= .13$ (life expectancy: 60 years)
δ	$= .06$
γ	$= 1.044$ (PWT: 1985-2014)
R	$= 1.030$ (King and Low, 2014: 1985-2014)
$\{\rho_n\}_n$	match $\{NX_{nt}/f_n k_n^{\alpha_n} H_{nt}\}_n$ (WIOD)
$\{\alpha_n\}_n$	match 1$-$ country-n labour share (PWT)
$\{\eta_n\}_n$	match $\{k_n\}_n$ (PWT)
$\{\sigma_{sn}\}_{s,n}$	match country-n, sector-s spending share (WIOD)
$\{\mu_{sn}\}_{s,n}$	match country-n, sector-s input share (WIOD)
$\{\theta_s\}_s$	match trade elasticities (Caliendo and Parro, 2015; Costinot and Rodríguez-Clare, 2014): Table A.2
$\{Z_{sn}/Z_{sUSA}\}_{s,n\neq USA}$, $\left\{\tau_{sn'n}/\left(\tau_{sn'n'}^{1/2}\tau_{snn}^{1/2}\right)\right\}_{s,n',n}$	match sector-level bilateral trade flows (WIOD)
$\{Z_{sUSA}\}_s$ $\{\tau_{snn}\}_{s,n}$	match $\{y_n\}_n$ (PWT)

Table 2: Calibration Overview

For parameter definitions, see Section 2. The data sources and calibration strategy are described in detail in Section 3.

$\lvert \ln \tau_{n'n} - \ln \tau_{nn'} \rvert$					
# obs.	mean	st. dev.	10th pctl.	median	90th pctl.
820	.079	.067	.011	.063	.528

Table 3: Calibration-implied asymmetries in trade wedges

$\tau_{n'n}$ represents the ad-valorem equivalent of the calibrated weighted average trade wedge applying to imports by country n from n', as defined in equation (24). Calibrations are based on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14. The data covers 40 individual economies and the rest of the world.

Dep. var.: $\lvert \ln \tau_{n'n} - \ln \tau_{nn'} \rvert$				
	(1)	(2)	(3)	(4)
log dist.	.010*** (.002)	.009***(.002)	.011**(.005)	.005 (.007)
contiguous	-.008 (.008)	-.014 (.009)	-.013 (.010)	-.014 (.011)
com. lang.		.003 (.015)	.002 (.015)	.010 (.016)
colonial		.022 (.018)	.024 (.019)	.030* (.016)
com. curr.		-.008 (.006)	-.005*** (.007)	-.006 (.009)
FTA			.015 (.011)	-.001 (.012)
EU			-.013* (.007)	.013 (.012)
country F.E.	No	No	No	Yes
# obs.	780	780	780	780
R^2	.03	.04	.07	.22

* $p < .10$; ** $p < .05$; ***$p < .01$;

Table 4: Asymmetries in trade wedges and gravity variables

Robust standard errors in parentheses. $\tau_{n'n}$ represents the ad-valorem equivalent of the calibrated weighted average trade wedge applying to imports by country n from n', as defined in equation (24). Calibrations are based on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14. The data covers 40 individual economies and the rest of the world, but the rest of the world is not included in the regression analysis. "Log dist." is the log of population-weighted distance between countries n' and n; "contiguous" is a dummy which takes value 1 if n' and n share a common border, 0 otherwise; "com. lang" is a dummy which takes value 1 if n' and n share an official language, 0 otherwise; "colonial" is a dummy which takes value 1 if n' and n share a colonial history, 0 otherwise; "com. curr." is a dummy which takes value 1 if n' and n share a currency, 0 otherwise; "FTA" is a dummy which takes value 1 if n' and n are parties to a free-trade agreement, 0 otherwise; "EU" is a dummy which takes value 1 if n' and n are both EU members, 0 otherwise.

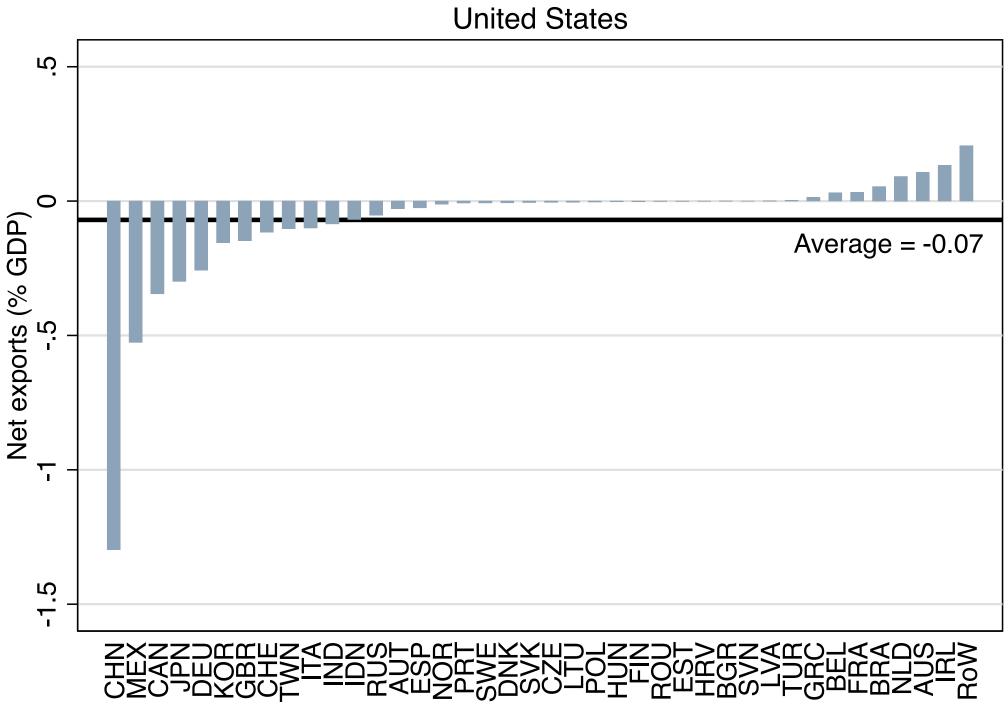


Figure 1: U.S. bilateral net exports, 2010-2014

"Net exports (% GDP)" refers to the total net exports of the United States vis-à-vis the horizontal-axis country, expressed as a percentage of U.S. GDP. All data is based on WIOD (2016 release), average for the years 2010-14.

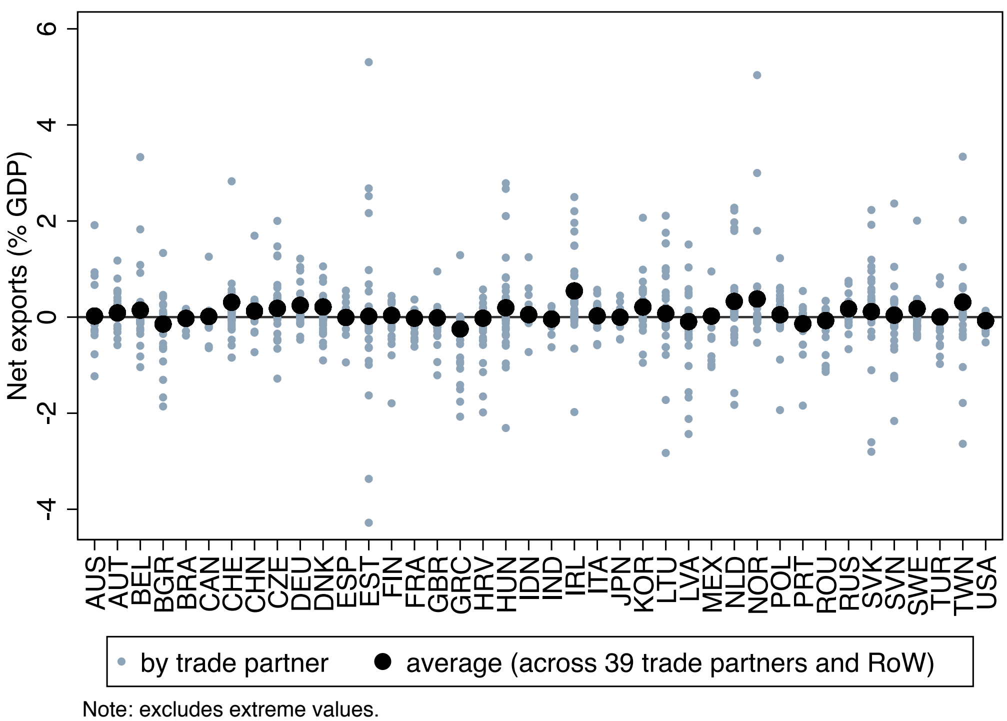


Figure 2: Bilateral net exports for 40 economies, 2010-2014

"Net exports (% GDP)" refers to the total net exports of the horizontal-axis country vis-à-vis a specific trade partner (blue dot) or the average trade partner (black dot), expressed as a percentage of the horizontal-axis country's GDP. All data is based on WIOD (2016 release), average for the years 2010-14.

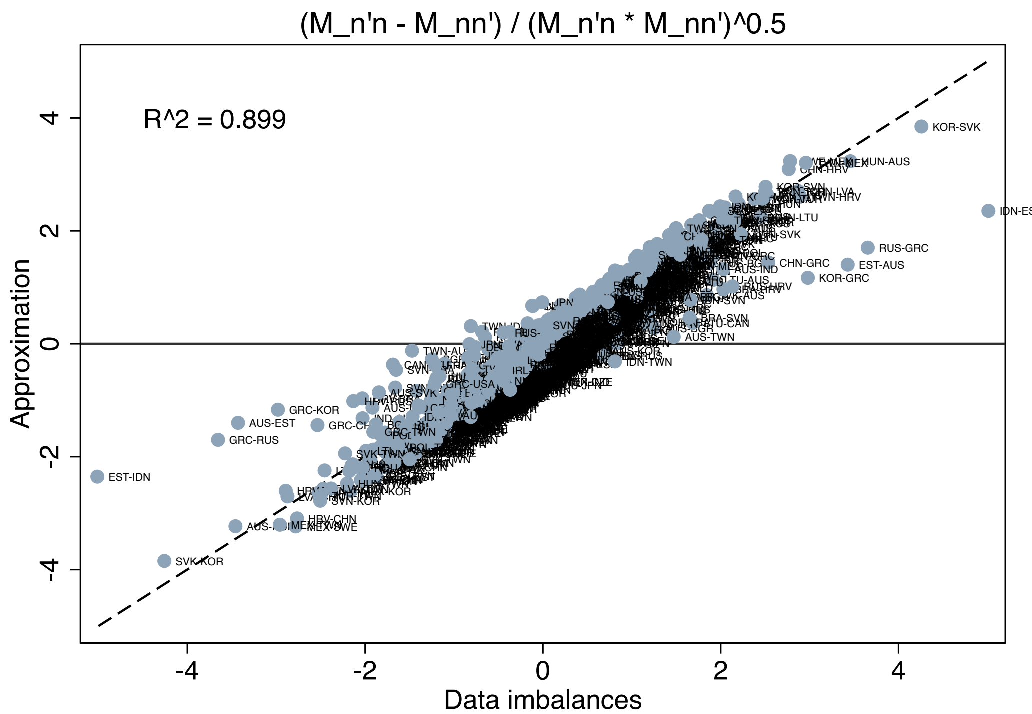


Figure 3: Approximated and actual trade imbalances

"Data imbalances" refers to $(M_{n'nt} - M_{nn't}) / (M_{nnt}M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. "Approximation" is the first-order linear approximation of this term, described in expression (19). All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 economies and the rest of the world.

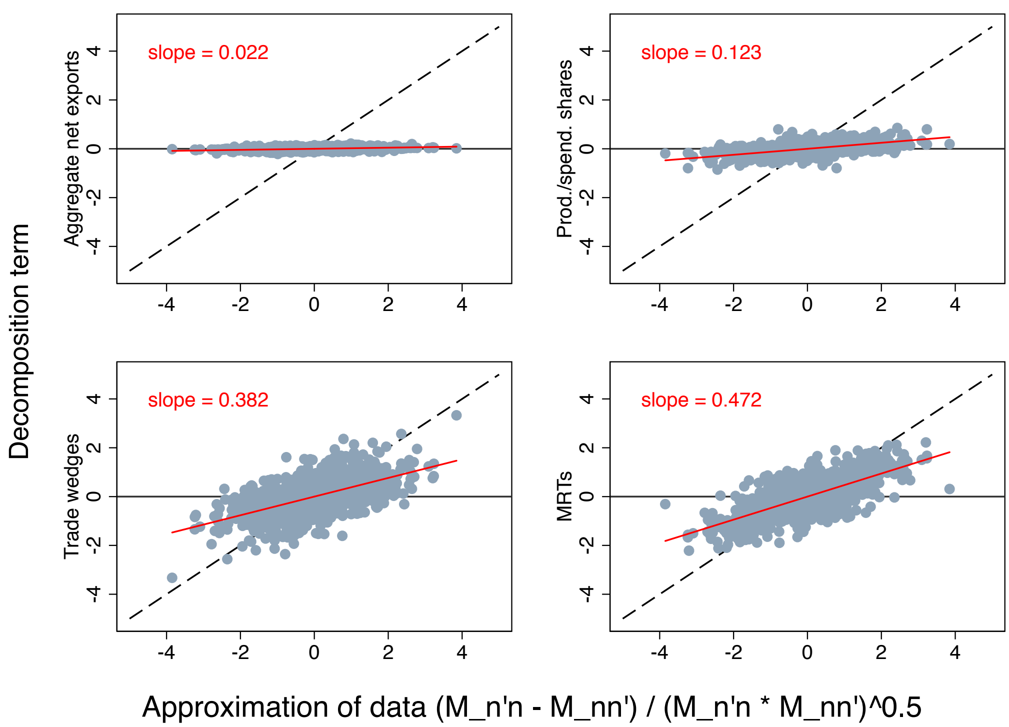


Figure 4: Variance decomposition

In each panel, the horizontal-axis variable is the first-order linear approximation of $(M_{n'nt} - M_{nn't}) / (M_{nnt}M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. The vertical-axis variable is one each of the four right-hand-side terms in expression (19). The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 individual economies and the rest of the world.

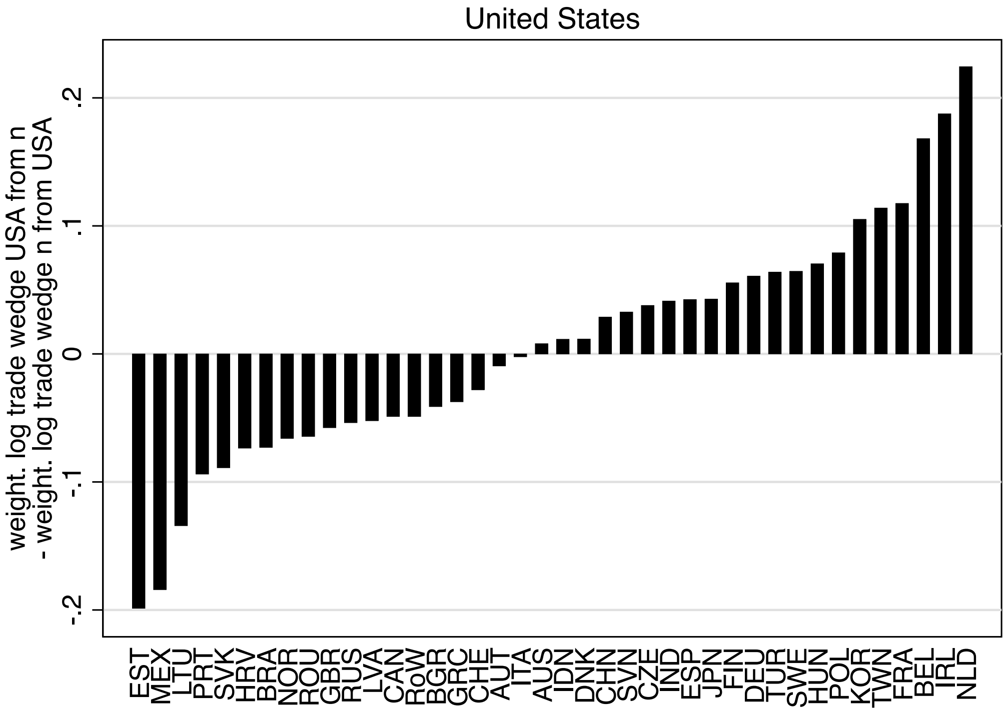


Figure 5: Model-implied trade-wedge asymmetries in U.S. bilateral trade

Each bar represents $\ln \tau_{nUSA} - \ln \tau_{USAn}$, where $\tau_{n'n}$ is the ad-valorem equivalent of the calibrated weighted average trade wedge applying to imports by country n from n', as defined in equation (24), and n is the horizontal-axis country. Calibrations are based on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

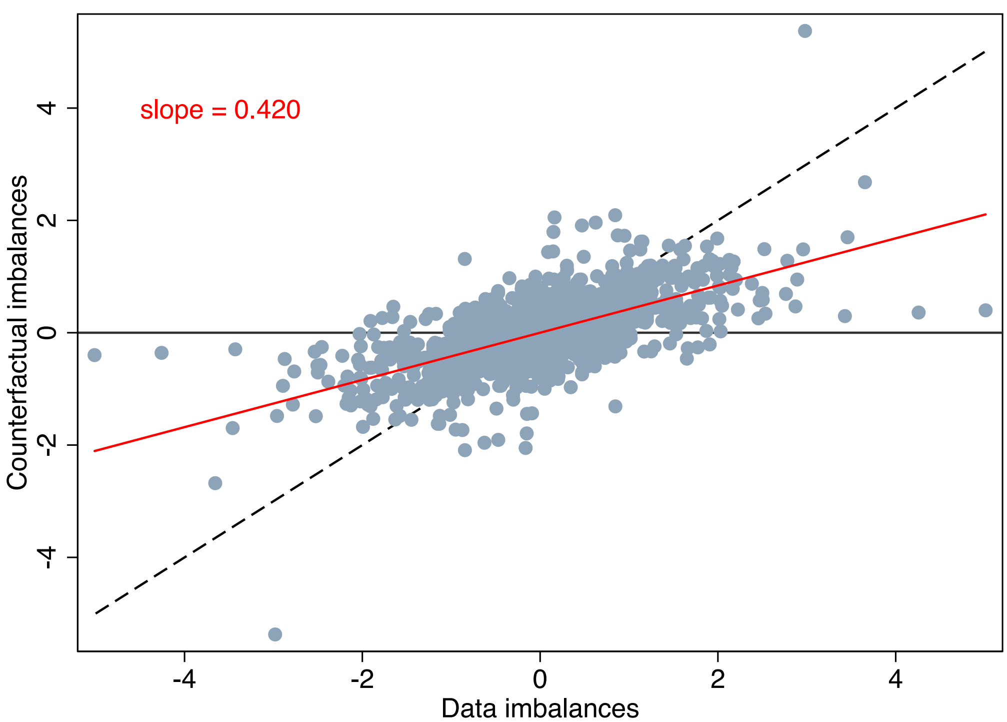


Figure 6: Bilateral imbalances under global trade-wedge symmetry

"Data imbalances" refers to $(M_{n'nt} - M_{nn't}) / (M_{nnt} M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. "Counterfactual imbalances" refers to the corresponding term in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 5.2. The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2016 release), average for the years 2010-14. The data covers 40 economies and the rest of the world.

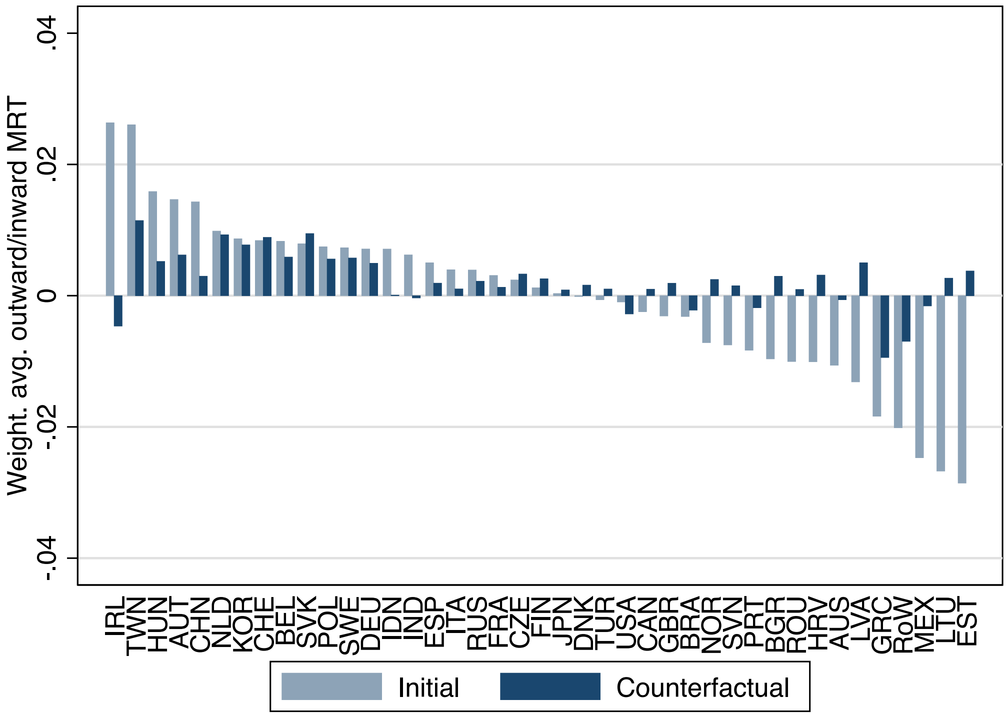


Figure 7: Average outward-inward MRT gap under global trade-wedge symmetry

Bars represent the weighted average gap between the outward and inward MRT for the horizontal-axis country, as defined in equation (26). "Initial" refers to the steady state of our calibrated model. "Counterfactual" refers to the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 5.2. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

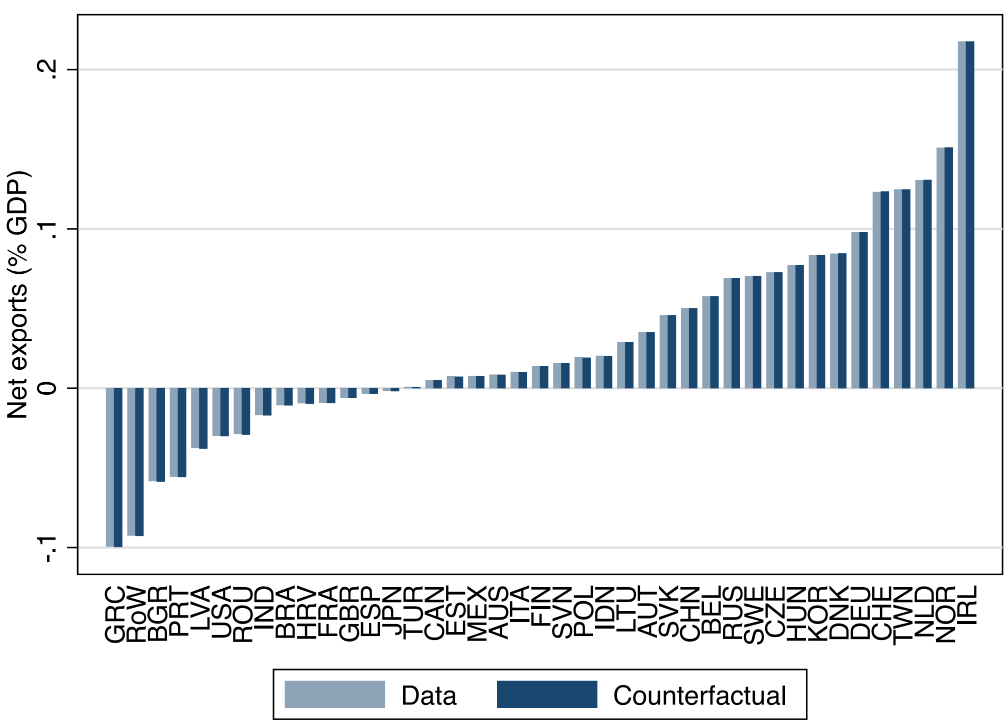


Figure 8: Aggregate trade balances under global trade-wedge symmetry

Bars represent the aggregate net exports of the horizontal-axis country, expressed as a percentage of GDP. "Data" refers to actual net exports. "Counterfactual" refers to net exports in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 5.2. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

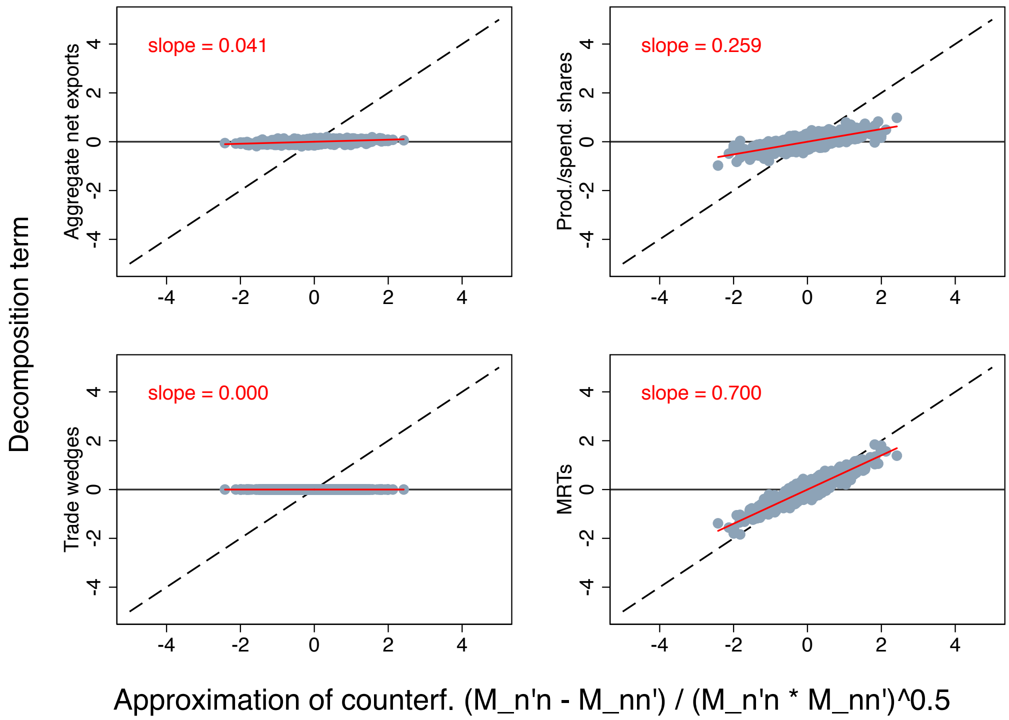


Figure 9: Variance decomposition under global trade-wedge symmetry

In each panel, the horizontal-axis variable is the first-order linear approximation of $(M_{n'nt} - M_{nn't}) / (M_{nnt}M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. The vertical-axis variable is one each of the four right-hand-side terms in expression (19). The red line represents the line of best fit, whose respective slope is also printed in red. Counterfactual steady state with symmetric trade wedges for 40 individual economies and the rest of the world in 2010-14, as described in Section 5.2.

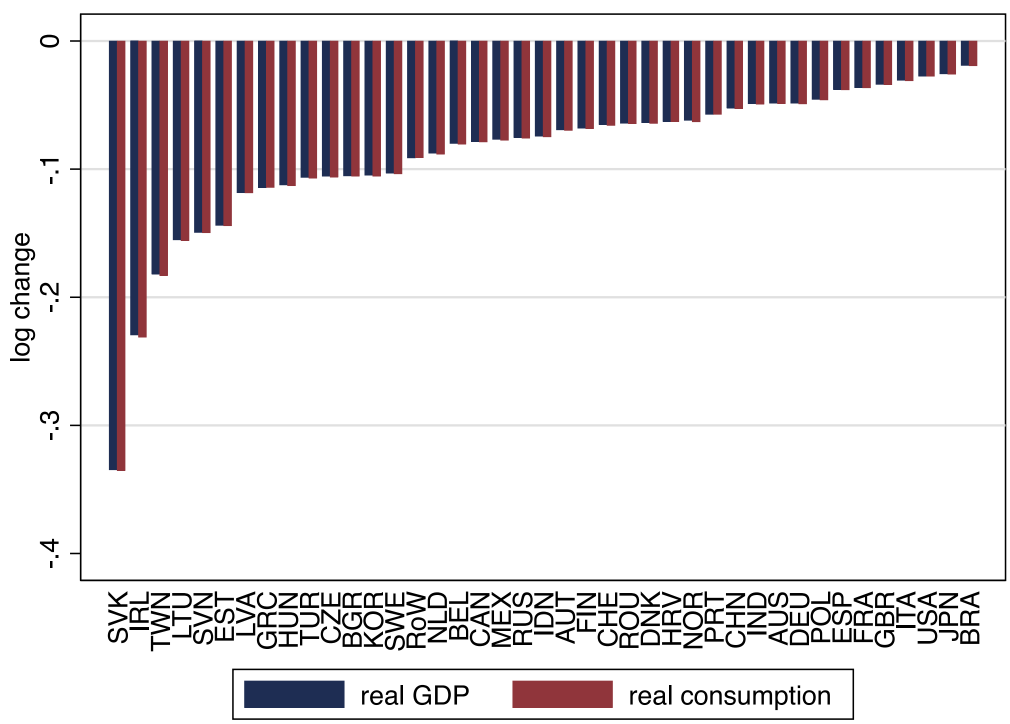


Figure 10: Impact of global trade-wedge symmetry on real GDP and consumption

Log change in real per-capita GDP and consumption relative to data in a counterfactual steady in which all bilateral trade wedges are made symmetric, as described in Section 5.2. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

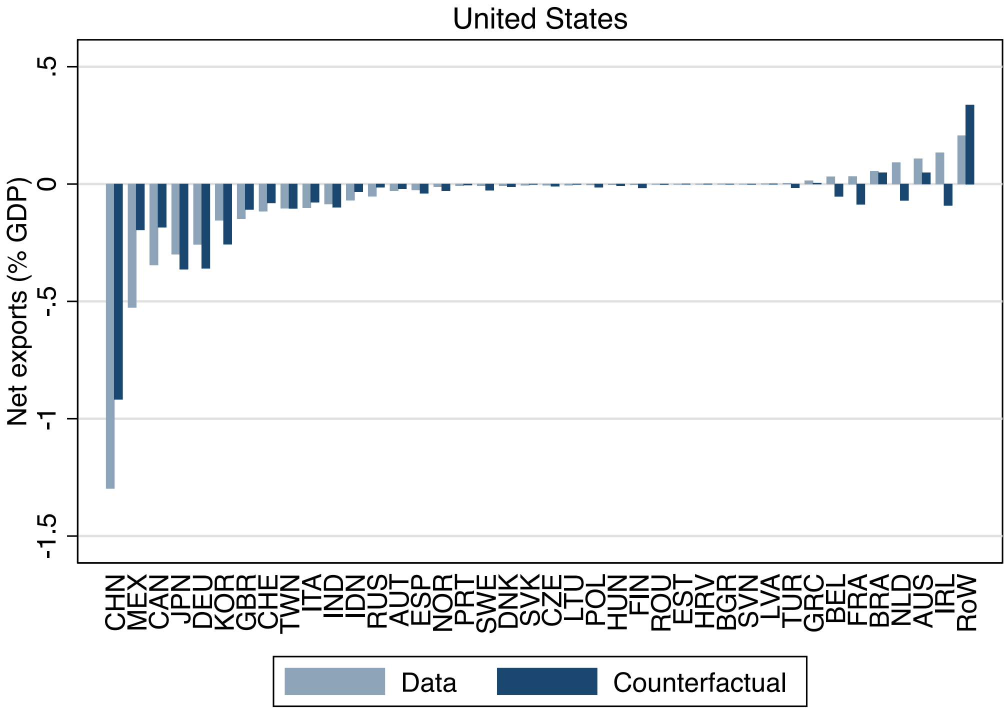
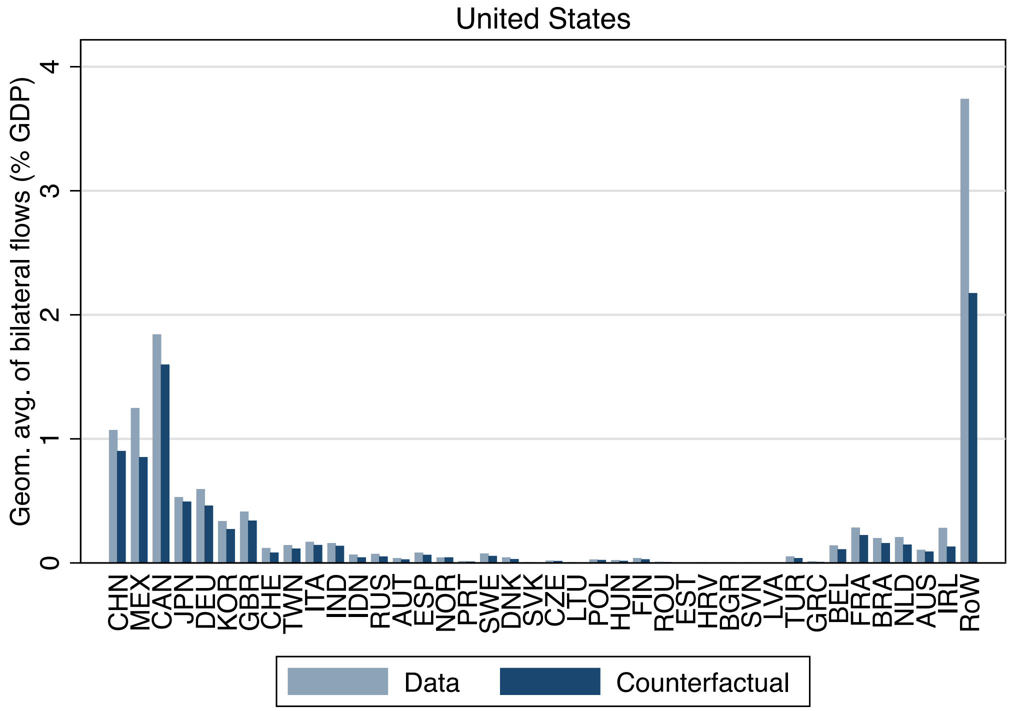
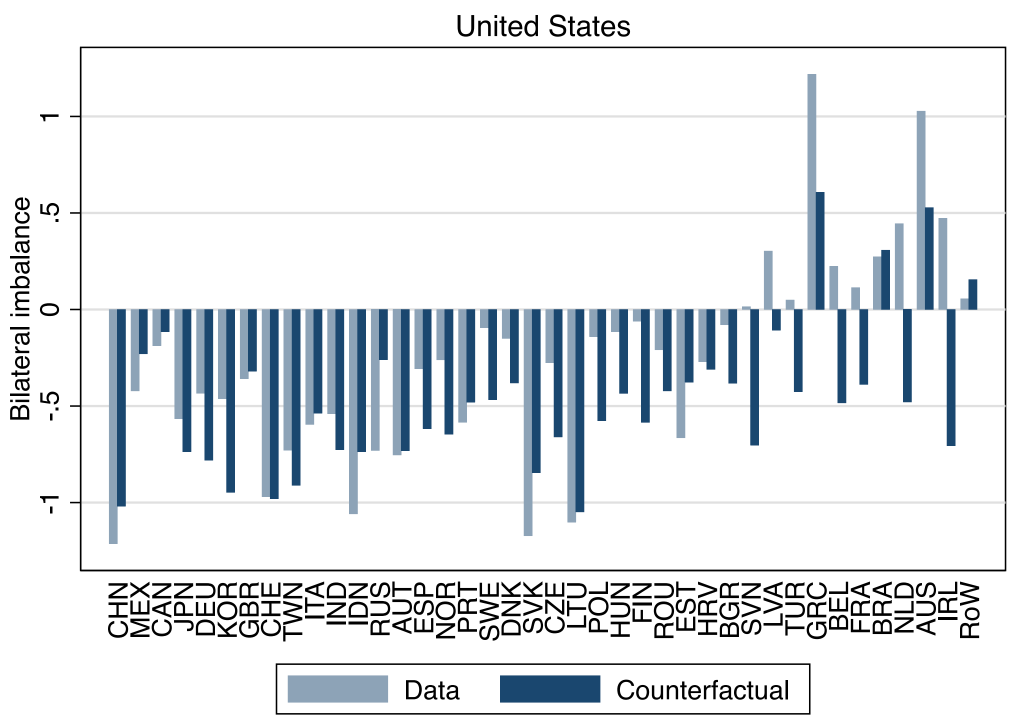


Figure 11: U.S. bilateral net exports under global trade-wedge symmetry

"Net exports (% GDP)" refers to the total net exports of the United States vis-à-vis the horizontal-axis country, expressed as a percentage of U.S. GDP. "Data" refers to actual bilateral net exports. "Counterfactual" refers to bilateral net exports in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 5.2. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.



Panel A: Changes in in the geometric average of trade flows (as % of GDP) with given trading partner



Panel B: Changes in the difference of bilateral trade flows relative to the geometric average of flows

Figure 12: Decomposing changes in U.S. bilateral net exports under trade-wedge symmetry

The "geometric average of bilateral flows (% GDP)" refers to $100 \times \left(M_{n.USA,t} M_{USA,nt}\right)^{1/2} / P_{USA} Y_{USA,t}$; and the "bilateral imbalance" refers to $\left(M_{USA,nt} - M_{n,USA,t}\right) / \left(M_{n.USA,t} M_{USA,nt}\right)^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. "Data" refers to actual components of bilateral net exports. "Counterfactual" refers to components of bilateral net exports in the counterfactual steady state in which all bilateral trade wedges are made symmetric, as described in Section 5.2. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

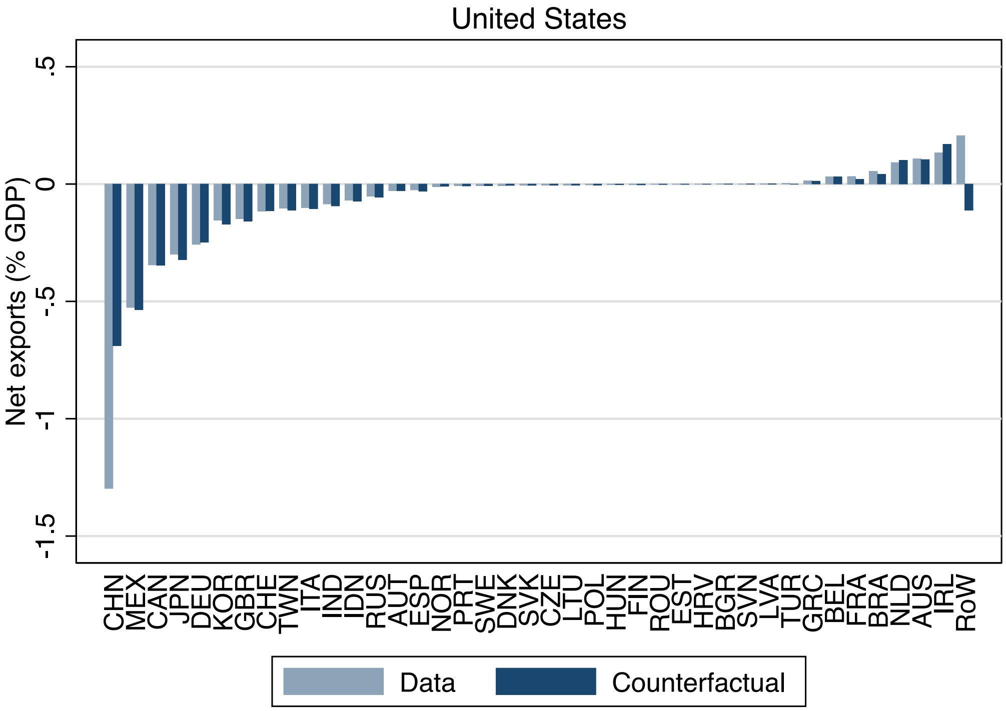


Figure 13: U.S. bilateral net exports in the wake of the USA-CHN trade war

"Net exports (% GDP)" refers to the total net exports of the United States vis-à-vis the horizontal-axis country, expressed as a percentage of U.S. GDP. "Data" refers to actual bilateral net exports. "Counterfactual" refers to bilateral net exports in the steady state of the USA-CHN trade-war counterfactual, as described in Section 5.3 and Appendix A4. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

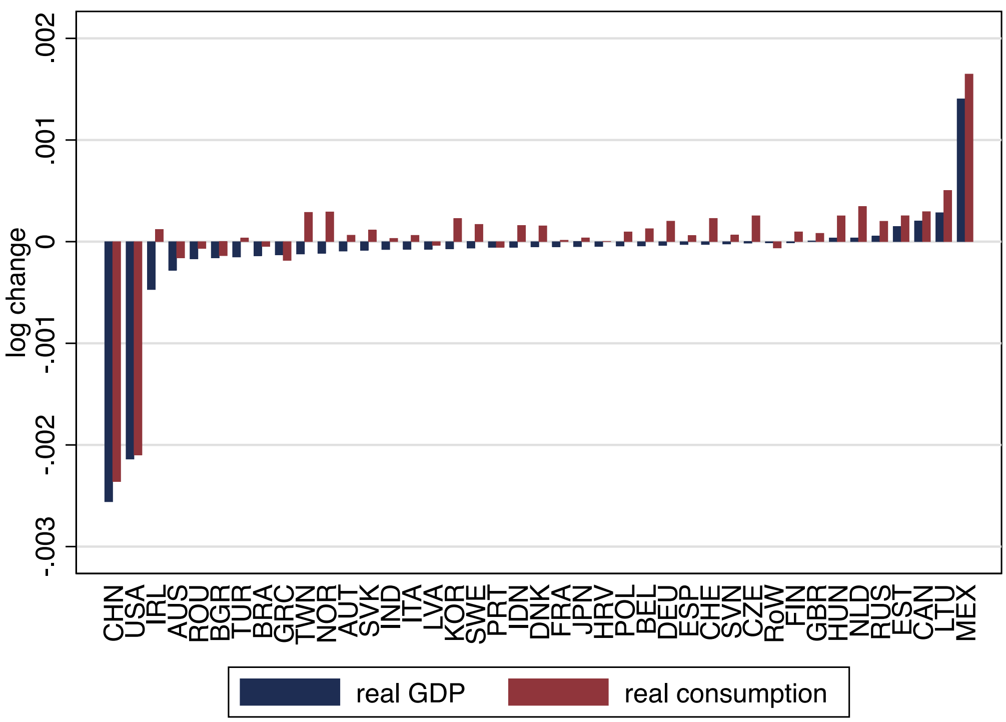


Figure 14: Impact of USA-CHN trade war on real GDP and consumption

Log change in real per-capita GDP and consumption relative to data in the USA-CHN trade-war steady state, as described in Section 5.3 and Appendix A4. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

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A Appendix

A.1 Dynamic Model

A.1.1 Agents' Optimality

The utility maximisation problem of an agent born in t' can be written as

$$\max_{\{C_{nt}(t')\}_{t=t'}^{\infty}} \sum_{t=t'}^{\infty} \left(\frac{1-\xi}{1+\rho_n}\right)^{t-t'} \ln C_{nt}\left(t'\right) \tag{29}$$

subject to

$$P_{nt}^{C} C_{nt}\left(t'\right) + P_{nt}^{I} I_{nt}\left(t'\right) + B_{nt+1}\left(t'\right) = w_{nt} H_{nt} + \frac{r_{nt}}{1-\xi} K_{nt}\left(t'\right) + \frac{R_t}{1-\xi} B_{nt}\left(t'\right), \tag{30}$$

$$K_{nt+1}\left(t'\right) = I_{nt}\left(t'\right) + \left(1-\delta\right) K_{nt}\left(t'\right), \tag{31}$$

$$K_{nt'}\left(t'\right) = B_{nt'}\left(t'\right) = 0, \tag{32}$$

where $I_{nt}\left(t'\right)$ is the agent's investment in t; $B_{nt}\left(t'\right)$ denotes bond holdings; $K_{nt}\left(t'\right)$ denotes capital holdings; P_{nt}^{C} is the final-consumption price level; P_{nt}^{I} is the investment price level; w_{nt} is the wage rate; and r_{nt} is the rental rate of capital in n. The resulting Euler equation is

$$\frac{C_{nt+1}\left(t'\right)}{C_{nt}\left(t'\right)} = \frac{P_{nt}^{C}}{P_{nt+1}^{C}} \frac{R_{t+1}}{1+\rho_n}, \tag{33}$$

and the optimal portfolio requires

$$\frac{r_{nt+1} + P_{nt+1}^{I}\left(1-\delta\right)}{P_{nt}^{I}} = R_{t+1}. \tag{34}$$

A.1.2 Steady-State Optimal Savings

In steady state, we can analytically characterise the consumption and savings decisions of an agent born in period t' as a function of their period-t asset and human wealth:

$$P_n C_{nt}\left(t'\right) = \frac{\rho_n + \xi}{\left(1-\xi\right)\left(1+\rho_n\right)} R A_{nt}\left(t'\right) + \frac{R\left(\rho_n + \xi\right)}{\left[R - \gamma\left(1-\xi\right)\right]\left(1+\rho_n\right)} w_n H_{nt}, \tag{35}$$

$$A_{nt+1}\left(t'\right) = \frac{1}{1+\rho_n} R A_{nt}\left(t'\right) + \frac{\left[R - \gamma\left(1+\rho_n\right)\right]\left(1-\xi\right)}{\left[R - \gamma\left(1-\xi\right)\right]\left(1+\rho_n\right)} w_n H_{nt}. \tag{36}$$

Define $A_{nt} \equiv \left(1-\xi\right)^{-1} \sum_{t'=-\infty}^{t} \xi \left(1-\xi\right)^{t-t'} A_{nt}\left(t'\right)$. Then,

$$a_{nt+1} = \frac{1-\xi}{\gamma}\left[\frac{R}{1+\rho_n} a_{nt} + \frac{R - \gamma\left(1+\rho_n\right)}{\left[R - \gamma\left(1-\xi\right)\right]\left(1+\rho_n\right)} w_n\right], \tag{37}$$

where $a_{nt} \equiv A_{nt}/H_{nt}$. There is a stationary distribution of assets in steady state as long as $\frac{1-\xi}{1+\rho_n}\frac{R}{\gamma} < 1$. In that case,

$$A_{nt} = \frac{(1-\xi)\left[R-\gamma\left(1+\rho_n\right)\right]\left(1-\alpha_n\right)}{\left[\gamma\left(1+\rho_n\right)-R\left(1-\xi\right)\right]\left[R-\gamma\left(1-\xi\right)\right]} f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}, \tag{38}$$

$$P_n C_{nt} = \frac{\gamma\xi\left(\rho_n+\xi\right) R\left(1-\alpha_n\right)}{\left[\gamma\left(1+\rho_n\right)-R\left(1-\xi\right)\right]\left[R-\gamma\left(1-\xi\right)\right]} f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}. \tag{39}$$

A.1.3 Steady-State Net Exports

In steady state,

$$K_{nt} = \frac{\alpha_n}{\eta_n P_n\left(R-1+\delta\right)} f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}. \tag{40}$$

This in turn implies

$$\eta_n P_n I_{nt} = \frac{\alpha_n\left(\gamma-1+\delta\right)}{R-1+\delta} f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n}. \tag{41}$$

From the definition of GDP,

$$f_n K_{nt}^{\alpha_n} H_{nt}^{1-\alpha_n} = P_n C_{nt} + \eta_n P_n I_{nt} + NX_{nt}. \tag{42}$$

This, together with (39) and (41), gives us the steady-state trade balance.

A.2 Approximating Bilateral Trade Imbalances

Rewrite equation (13) as

$$M_{sn'nt} = \left(\frac{\tau_{sn'n}}{O_{sn'}P_{sn}}\right)^{-\theta_s} q_{sn'}\sigma_{sn}\frac{p_n Q_{nt} p_{n'} Q_{n't}}{\sum_n p_n Q_{nt}}\left(1-\frac{NX_{nt}}{p_n Q_{nt}}\right), \tag{43}$$

where $M_{n'n} \equiv \sum_s M_{sn'n}$. Then,

$$\frac{M_{sn'nt}}{M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}}} = \left(\frac{M_{sn'nt}M_{snn't}}{M_{n'nt}M_{nn't}}\right)^{\frac{1}{2}}\left(\frac{1-NX_{nt}/p_n Q_{nt}}{1-NX_{n't}/p_{n'}Q_{n't}}\right)^{\frac{1}{2}} \times$$

$$\times\left(\frac{q_{sn'}\sigma_{sn}}{q_{sn}\sigma_{sn'}}\right)^{\frac{1}{2}}\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)^{-\frac{\theta_s}{2}}\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)^{-\frac{\theta_s}{2}}. \tag{44}$$

Using a first-order Taylor approximation around the point $\left(\ln\Omega_1, \ln\Omega_2, \ln\Omega_3^{1/\theta_s}, \ln\Omega_4^{1/\theta_s}\right)$, we can write

$$\frac{M_{sn'nt}}{M_{n'nt}^{\frac{1}{2}} M_{nn't}^{\frac{1}{2}}}\left[\ln\left(\frac{1-NX_{nt}/p_n Q_{nt}}{1-NX_{n't}/p_{n'}Q_{n't}}\right), \ln\left(\frac{q_{sn'}\sigma_{sn}}{q_{sn}\sigma_{sn'}}\right), \ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right), \ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)\right] \equiv$$

$$\left(\frac{M_{sn'n}M_{snn'}}{M_{n'n}M_{nn'}}\right)^{\frac{1}{2}} e^{\frac{1}{2}\ln\left(\frac{1-NX_{nt}/p_nQ_{nt}}{1-NX_{n't}/p_{n'}Q_{n't}}\right)+\frac{1}{2}\ln\left(\frac{q_{sn'}\sigma_{sn}}{q_{sn}\sigma_{sn'}}\right)-\frac{\theta_s}{2}\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)-\frac{\theta_s}{2}\ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)} =$$

$$\simeq \left(\frac{M_{sn'n}M_{snn'}}{M_{n'n}M_{nn'}}\right)^{\frac{1}{2}} \left(\frac{\Omega_1\Omega_2}{\Omega_3\Omega_4}\right)^{\frac{1}{2}} \left\{1+\frac{1}{2}\left[\ln\left(\frac{1-NX_{nt}/p_nQ_{nt}}{1-NX_{n't}/p_{n'}Q_{n't}}\right)-\ln\Omega_1\right]+\right.$$

$$\left.+\frac{1}{2}\left[\ln\left(\frac{q_{sn'}\sigma_{sn}}{q_{sn}\sigma_{sn'}}\right)-\ln\Omega_2\right]-\frac{\theta_s}{2}\left[\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)-\ln\Omega_3^{\frac{1}{\theta_s}}\right]-\frac{\theta_s}{2}\left[\ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)-\ln\Omega_4^{\frac{1}{\theta_s}}\right]\right\}. \tag{45}$$

Hence,

$$nx_{n'n} = \frac{M_{n'n}-M_{nn'}}{M_{n'n}^{\frac{1}{2}}M_{nn'}^{\frac{1}{2}}} = \Omega\sum_s \left(\frac{M_{sn'n}M_{snn'}}{M_{n'n}M_{nn'}}\right)^{\frac{1}{2}} \times$$

$$\times\left\{\ln\left(\frac{1-NX_{nt}/p_nQ_{nt}}{1-NX_{n't}/p_{n'}Q_{n't}}\right)+\ln\left(\frac{q_{sn'}\sigma_{sn}}{q_{sn}\sigma_{sn'}}\right)-\theta_s\ln\left(\frac{\tau_{sn'n}}{\tau_{snn'}}\right)-\theta_s\ln\left(\frac{O_{sn}P_{sn'}}{O_{sn'}P_{sn}}\right)\right\}, \tag{46}$$

where $\Omega \equiv [\Omega_1\Omega_2/(\Omega_3\Omega_4)]^{1/2}$.

Let $\hat{nx}_{n'n}$ denote the data analogue of equation (46). Then,

$$\frac{Cov\left(nx_{n'n},\hat{nx}_{n'n}\right)}{Var\left(\hat{nx}_{n'n}\right)} = \Omega\frac{Cov\left(\frac{nx_{n'n}}{\Omega},\hat{nx}_{n'n}\right)}{Var\left(\hat{nx}_{n'n}\right)}.$$

We can now choose a point Ω such that

$$\frac{Cov\left(nx_{n'n},\hat{nx}_{n'n}\right)}{Var\left(\hat{nx}_{n'n}\right)} = 1.$$

Note, however, that this is merely a presentationally convenient normalisation, which has no substantive impact on the any of the quantitative results presented in Section 4.2.

A.3 Variance Decomposition for 1995-1999

A.3.1 Data

To compile the data for 1995-1999 decomposition of the variation in bilateral imbalances, we proceed as described in Section 3 – with one exception: we use the 2013 release of WIOD (whose data tables start in 1995), instead of the 2016 release (whose data tables start in 2000). The data allow us to aggregate trade and spending values to the same 31 sectors as described in Section 3.1 (and shown in Table A1). However, in the 2013 release Croatia, Norway and Switzerland are not covered as individual countries but grouped with the "rest of the world". For this reason, the 1995-1999 data only cover 37 individual countries and the rest of the world, which yields ($38 \times 37/2 =$) 703 distinct bilateral trade imbalances.

[Insert Figure A1 here]

Figure A1 correlates the bilateral imbalances available in both periods with one another, using only the 703 surpluses for 1995-1999. The figure indicates that there is a fairly high degree of persistence: the correlation of the 1995-99 surplus with the 2010-14 value of the same trade balance is .36. Moreover, more than two thirds of the bilateral balances which were in surplus in 1995-1999 were still in surplus in 2010-14.

A.3.2 Variance Decomposition

Figure A2 is the analogue for the 1995-1999 period of Figure 4 in the main text. The quantitative results of the variance decomposition are remarkably similar.

[Insert Figure A2 here]

Variation in countries' aggregate trade balances accounts for 3% of the variation in bilateral trade imbalances. Differences in production and spending patterns ("triangular trade") account for 9.5% of the variation, and asymmetric trade wedges account for 35%. The remaining 52% are due to variation in the ratio of outward to inward MRTs.

A.4 U.S.-China Trade War

We obtain data on tariff changes and import values at the 10-digit level of HS for the U.S. from Bown (2019). For China, we take data on tariff changes and import values at the 8-digit level of HS from Bown et al. (2019).[19] Using a concordance from HS to ISIC Rev. 4, we aggregate the tariff changes at the (roughly) 2-digit level of ISIC used in the WIOD (2016 release). We then aggregate further to obtain tariff changes for the coarser set of sectors used throughout this paper (see Section 3). The resulting changes in trade wedges, upon which we base our counterfactual, are shown in Table A4. The remainder of this section reports additional results for the trade-war counterfactual.

[Insert Figure A3 here]

Figure A3 shows that, as with our global trade-wedge-symmetry counterfactual, the trade war has the effect of narrowing the average gap of outward to inward MRTs across countries. Unsurprisingly, this effect is much smaller than in our first counterfactual. It is, however, noteworthy that the effect is larger for some third countries − notably, Ireland and Taiwan − than it is for the U.S. and China themselves. As can be seen from Figure A4, the effect on aggregate trade balances remains imperceptible.

[Insert Figure A4 here]

[19] We would like to thank Chad Bown for making this data available.

Figure A5 decomposes the changes in U.S. bilateral net exports into the changes in the average value of trade trade flows with each U.S. trade partners, and changes in the "trade imbalance" component. It is clear from Panel A that the primary impact of the U.S. and Chinese tariffs on average trade values is to reduce bilateral flows between the U.S. and China. There is also evidence of some trade diversion, as U.S. trade flows with Mexico, Germany and Ireland rise slightly, but these effects are of much smaller magnitude. Panel B documents that the (proportional) imbalance between the U.S. and China also declines, since average U.S. tariffs on China are somewhat higher than Chinese tariffs on the U.S. However, as a result, the proportional deficits of the U.S. with most of its trade partners increase, U.S. surpluses decline, and there are even some sign changes − most significantly vis-à-vis the rest of the world.

[Insert Figure A5 here]

The changes in U.S. imbalances as a result of the trade war have little effect on the global distribution of bilateral imbalances: the correlation between the empirical bilateral imbalances and their counterfactual counterparts is .98. As a result, from a global viewpoint, the U.S.-China trade war does little to alter the relative roles of the three drivers of imbalances, as described in Sections 4 and 5.2.

A.5 Simple versus Log Difference in Bilateral Trade Flows

In their pioneering analysis of bilateral trade balances, Davis and Weinstein (2002) investigate how much of the variation across country pairs in the simple bilateral difference in trade flows (in US$) can be explained using a gravity equation under the assumption of symmetric trade barriers. They conclude that a large portion remains unexplained − and term this the "mystery of the excess trade balances". However, their gravity equation does not control for MRTs either through appropriate fixed effects or a theory-consistent non-linear regression model.

By contrast, our analysis focuses on variation across country pairs in the (approximate) *log difference* in bilateral trade flows. Our approach is fully structural, and takes account of multilateral resistance. We find that, when considering trade imbalances in the log difference, the "mystery" remains: a large part of the variation in imbalances cannot be explained unless we allow for asymmetric trade wedges. As argued in Section 2.3.2, we consider this the fairest test of the ability of structural gravity to explain trade imbalances. Unlike the log difference between bilateral flows, the simple differences conflates the (well-understood) ability of structural gravity to explain variation in average trade flows across country pairs with the (less well-studied) inability of gravity to account for variation in the proportional gap between bilateral flows.

To give a sense of the effect of conflating the two, we estimate a gravity regression of the form

$$M_{n'n} = e^{\{\delta_{n'}+\delta_n+\delta_{n'n}+\varepsilon_{n'n}\}}, \tag{47}$$

where $\delta_{n'}$ is a country-n'-exporter dummy; δ_n is a country-n-importer dummy; $\delta_{n'n} = \delta_{nn'}$ is a country-pair dummy; and $\varepsilon_{n'n} \neq \varepsilon_{nn'}$ is a mean-zero error. As the left-hand-side variable, we use the 1995-1999 average value of bilateral trade flows from WIOD (2013 release) for 37 individual economies and the "rest of the world" (= 1406 pairs). We use this data to facilitate comparison with Davis and Weinstein (2002), who use data for 1995. Based on our estimates, we then construct

$$\hat{M}_{n'n} = e^{\left\{\hat{\delta}_{n'}+\hat{\delta}_n+\hat{\delta}_{n'n}\right\}}, \tag{48}$$

i.e. the gravity trade value exempting any trade-wedge asymmetries (the magnitude of which is captured by $\ln \hat{\varepsilon}_{n'n} - \ln \hat{\varepsilon}_{nn'}$).

[Insert Figure A6 here]

Figure A6 plots $\hat{M}_{n'n} - \hat{M}_{nn'}$ against $M_{n'n} - M_{nn'}$. The figure is analogous to Figure 1 in Davis and Weinstein (2002). However, while they find that the coefficient of fitted on actual trade imbalances is .06, in Figure A6 this coefficient is .65. This difference is due to the inclusion of country-exporter and -importer fixed effects to capture MRTs. Therefore, based on simple differences in bilateral trade flows, one might be led to conclude that a structural gravity model can explain most of the variation in bilateral imbalances in the absence of asymmetric trade wedges.[20]

[Insert Figure A7 here]

By contrast, Figure A7 plots $\ln \hat{M}_{n'n} - \ln \hat{M}_{nn'}$ against $\ln M_{n'n} - \ln M_{nn'}$. Figure A7 is much less dominated by a handful of large individual values than Figure A6. Nevertheless, the coefficient of fitted on actual trade imbalances is now only .30. This is quantitatively in line with the conclusion drawn in the present paper − that most of bilateral imbalances must be attributed to asymmetric trade wedges. It also shows that most of the "success" of structural gravity in Figure A6 is due to the well-documented success of estimations such as (47) in explaining the variation in the average value of bilateral trade flows across country pairs.

[20] Felbermayr and Yotov (2019) perform an analysis along the lines of equations (47) and (48) and, on this basis, argue that MRTs solve the "mystery of the excess trade balances".

A.6 Supplementary Tables

WIOD (2016)		Final data	
Country	Code	Country	Code
Australia	AUS	Australia	AUS
Austria	AUT	Austria	AUT
Belgium	BEL	Belgium	BEL
Brazil	BRA	Brazil	BRA
Bulgaria	BGR	Bulgaria	BGR
Canada	CAN	Canada	CAN
China	CHN	China	CHN
Croatia	HRV	Croatia	HRV
Cyprus	CYP	Rest of the World	RoW
Czech Republic	CZE	Czech Republic	CZE
Denmark	DNK	Denmark	DNK
Estonia	EST	Estonia	EST
Finland	FIN	Finland	FIN
France	FRA	France	FRA
Germany	DEU	Germany	DEU
Greece	GRC	Greece	GRC
Hungary	HUN	Hungary	HUN
India	IND	India	IND
Indonesia	IDN	Indonesia	IDN
Ireland	IRL	Ireland	IRL
Italy	ITA	Italy	ITA
Japan	JPN	Japan	JPN
Korea	KOR	Korea	KOR
Latvia	LVA	Latvia	LVA
Lithuania	LTU	Lithuania	LTU
Luxembourg	LUX	Rest of the World	RoW
Malta	MLT	Rest of the World	RoW
Mexico	MEX	Mexico	MEX
Netherlands	NLD	Netherlands	NLD
Norway	NOR	Norway	NOR
Poland	POL	Poland	POL
Portugal	PRT	Portugal	PRT
Rest of the World	RoW	Rest of the World	RoW
Romania	ROU	Romania	ROU
Russia	RUS	Russia	RUS
Slovakia	SVK	Slovakia	SVK
Slovenia	SVN	Slovenia	SVN
Spain	ESP	Spain	ESP
Sweden	SWE	Sweden	SWE
Switzerland	CHE	Switzerland	CHE
Taiwan	TWN	Taiwan	TWN
Turkey	TUR	Turkey	TUR
U.K.	GBR	U.K.	GBR
U.S.	USA	U.S.	USA

Table A1: Country sample

The "WIOD (2016)" column shows countries and regions as covered in the 2016 release of WIOD. The "Final data" column shows countries and regions as grouped for our analysis.

WIOD (2016)		Final data			
Sector	ISIC 2-dg.	New code	Sector	ISIC 2-dg.	New code
Crop and animal production...	1	1	Wholesale trade, except...	46	18
Forestry and logging	2	1	Retail trade, except of...	47	19
Fishing and aquaculture	3	1	Land transport and...	49	21
Mining and quarrying	5-9	2	Water transport	50	22
Manufacture of food products,...	10-12	3	Air transport	51	23
Manufacture of textiles,...	13-15	4	Warehousing and support...	52	24
Manufacture of wood and...	16	5	Postal and courier activities	53	25
Manufacture of paper and...	17	6	Accommodation and food...	55-56	20
Printing and reproduction...	18	6	Publishing activities	58	6
Manufacture of coke and...	19	7	Motion picture, video and...	59-60	6
Manufacture of chemicals...	20	8	Telecommunications	61	25
Manufacture of basic pharma...	21	8	Computer programming,...	62-63	28
Manufacture of rubber and...	22	9	Financial service activities,...	64	26
Manufacture of other non-metal...	23	10	Insurance, reinsurance and...	65	26
Manufacture of basic metals	24	11	Activities auxiliary to financial...	66	26
Manufacture of fabricated metal...	25	11	Real estate activities	68	27
Manufacture of computer,...	26	13	Legal and accounting activities;...	69-70	28
Manufacture of electrical equip...	27	13	Architectural and engineering...	71	28
Manufacture of machinery and...	28	12	Scientific research and...	72	28
Manufacture of motor vehicles,...	29	14	Advertising and market research	73	28
Manufacture of other transport...	30	14	Other professional, scientific...	74-75	28
Manufacture of furniture; other...	31-32	15	Administrative and support...	77-82	28
Repair and installation...	33	15	Public administration and...	84	31
Electricity, gas, steam and...	35	16	Education	85	29
Water collection, treatment...	36	16	Human health and social work...	86-88	30
Sewerage; waste collection,...	37-39	16	Other service activities	90-96	31
Construction	41-43	17	Activities of households...	97-98	28
Wholesale and retail...	45	18	Activities of extraterritorial...	99	31

Table A2: Sector sample

The "WIOD (2016)" column shows sector names and codes as covered in the 2016 release of WIOD. The "Final data" column shows the new codes for the sector groups created for our analysis.

Final data		
New code	Sector	Trade elasticity
1	Agriculture, hunting, forestry and fishing	8.11
2	Mining and quarrying	15.72
3	Food, beverages and tobacco	2.55
4	Textiles and textile products; leather, leather apparel and footwear	5.56
5	Wood and products of wood and cork	10.83
6	Pulp, paper; paper, printing and publishing	9.07
7	Coke, refined petroleum and nuclear fuel	51.08
8	Chemicals and chemical products	4.75
9	Rubber and plastics	1.66
10	Other non-metallic, mineral products	2.76
11	Basic metals and fabricated metal	7.99
12	Electrical and optical equipment	10.60
13	Machinery, nec	1.52
14	Transport equipment	0.37
15	Manufacturing, nec; recycling	5
16	Electricity, gas and water supply	5
17	Construction	5
18	Wholesale trade, commission trade, including motor vehicles and motorcycles	5
19	Retail trade, except of motor vehicles and motorcycles	5
20	Hotels and restaurants	5
21	Inland transport	5
22	Water transport	5
23	Air transport	5
24	Other supporting and auxiliary transport activities; activities of travel agencies	5
25	Post and telecommunications	5
26	Financial intermediation	5
27	Real estate activities	5
28	Other business activities	5
29	Education	5
30	Health and social work	5
31	Public admin, defence, social security and other public services	5

Table A3: Sector sample and trade elasticities

"New code" shows the new codes for the sector groups created for our analysis. "Sector" shows the corresponding sector names. "Trade elasticity" shows the corresponding trade elasticities. Trade elasticities are based on Caliendo and Parro (2015), and Costinot and Rodríguez-Clare (2014).

Final data			
New code	Sector	$\frac{d^{new}_{s,CHN,USA}}{d_{s,CHN,USA}}$	$\frac{d^{new}_{s,USA,CHN}}{d_{s,USA,CHN}}$
1	Agriculture, hunting, forestry and fishing	1.16	1.25
2	Mining and quarrying	1.06	1.10
3	Food, beverages and tobacco	1.19	1.19
4	Textiles and textile products; leather, leather apparel and footwear	1.05	1.14
5	Wood and products of wood and cork	1.20	1.19
6	Pulp, paper; paper, printing and publishing	1.20	1.16
7	Coke, refined petroleum and nuclear fuel	1.18	1.25
8	Chemicals and chemical products	1.14	1.11
9	Rubber and plastics	1.13	1.08
10	Other non-metallic, mineral products	1.17	1.12
11	Basic metals and fabricated metal	1.18	1.19
12	Electrical and optical equipment	1.18	1.10
13	Machinery, nec	1.11	1.08
14	Transport equipment	1.23	1.00
15	Manufacturing, nec; recycling	1.10	1.06
16	Electricity, gas and water supply	1.23	1.06

Table A4: Trade-cost changes as a result of the USA-CHN trade war

"New code" shows the new codes for the sector groups created for our analysis. "Sector" shows the corresponding sector names. $d^{new}_{sn'n}/d_{sn'n}$ shows the new iceberg cost for imports by country n from n' in sector s in the trade-war scenario. $d^{new}_{sn'n}/d_{sn'n} = 1$ for all s, $n'$and n not shown in the table. Iceberg-cost changes are based on data from Bown (2019) and Bown et al. (2019). See Appendix A4 for more details.

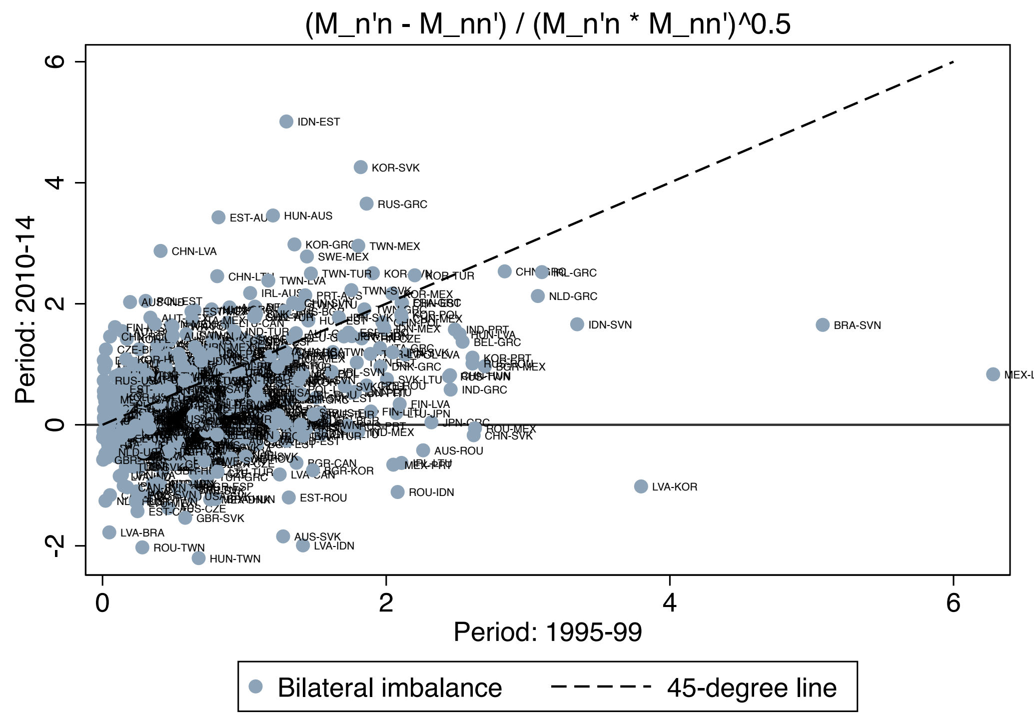


Figure A1: Bilateral trade imbalances, 2010-14 versus 1995-1999

"Bilateral imbalance" refers to $(M_{n'nt} - M_{nn't}) / (M_{nnt} M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. On the horizontal axis, all values are the average for the 2010-14 period. On the vertical axis, all values are the average for the 1995-1999 period. The 2010-14 data is based on WIOD (2016 release), the 1995-99 data on WIOD (2013 release). The chart covers 37 individual economies.

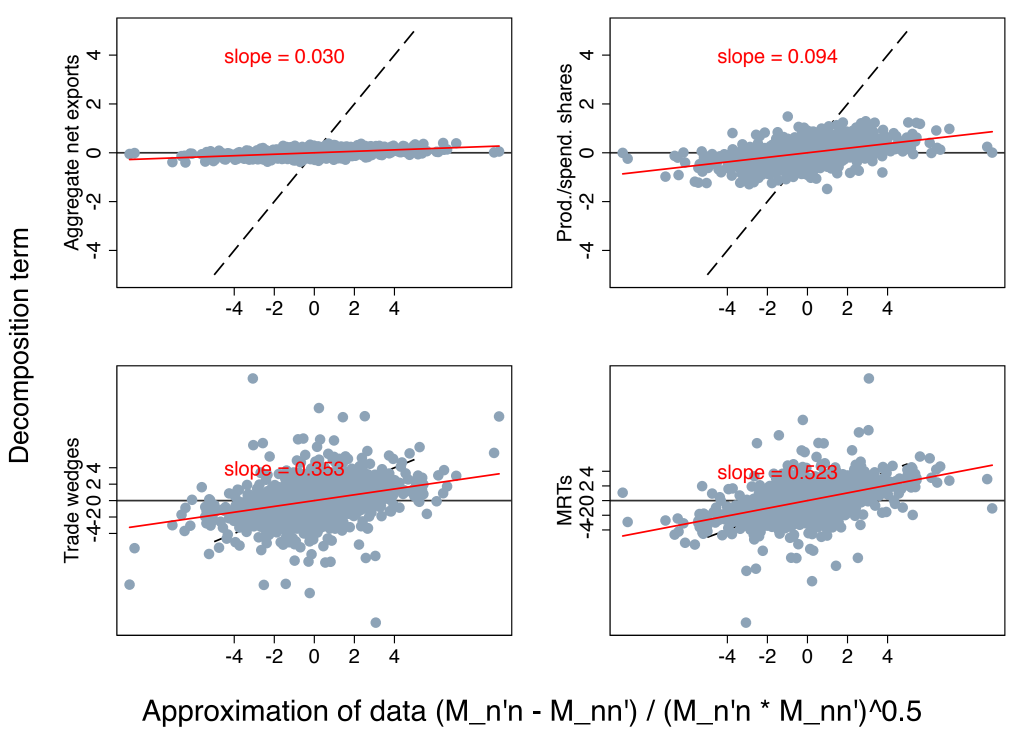


Figure A2: Variance decomposition for 1995-1999

In each panel, the horizontal-axis variable is the first-order linear approximation of $(M_{n'nt} - M_{nn't}) / (M_{nnt} M_{n'n't})^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. The vertical-axis variable is one each of the four right-hand-side terms in expression (19). The red line represents the line of best fit, whose respective slope is also printed in red. All data is based on WIOD (2013 release), average for the years 1995-99. The data covers 37 individual economies and the rest of the world.

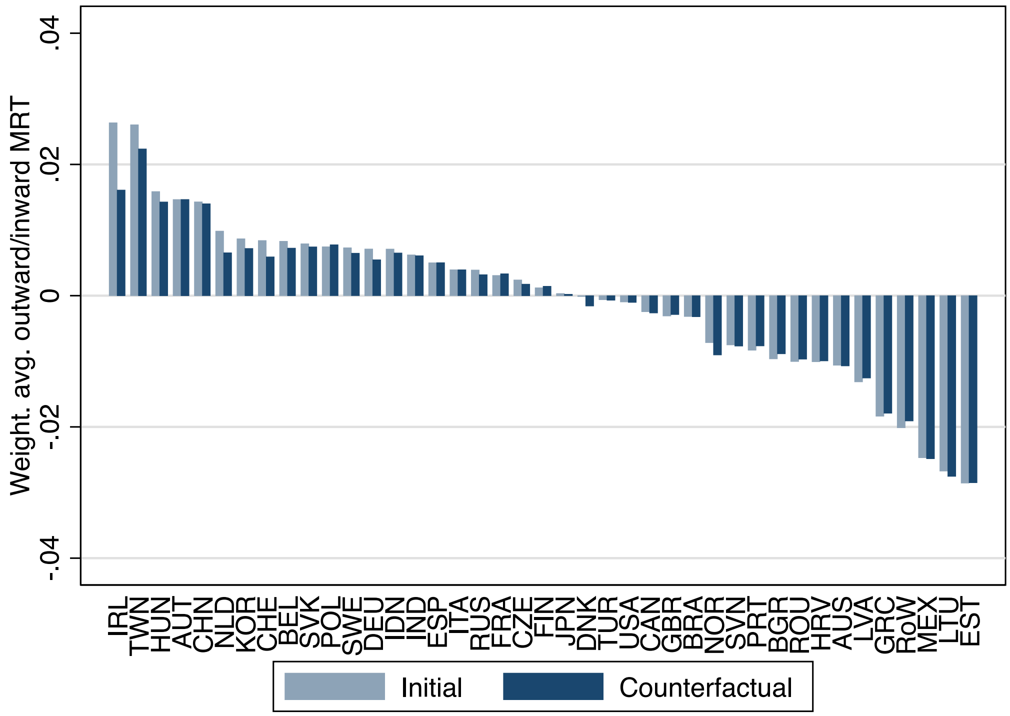


Figure A3: Average outward-inward MRT gap in the wake of the USA-CHN trade war

Bars represent the weighted average gap between the outward and inward MRT for the horizontal-axis country, as defined in equation (26). "Initial" refers to the steady state of our calibrated model. "Counterfactual" refers to the steady state of the USA-CHN trade-war counterfactual, as described in Section 5.3 and Appendix A4. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

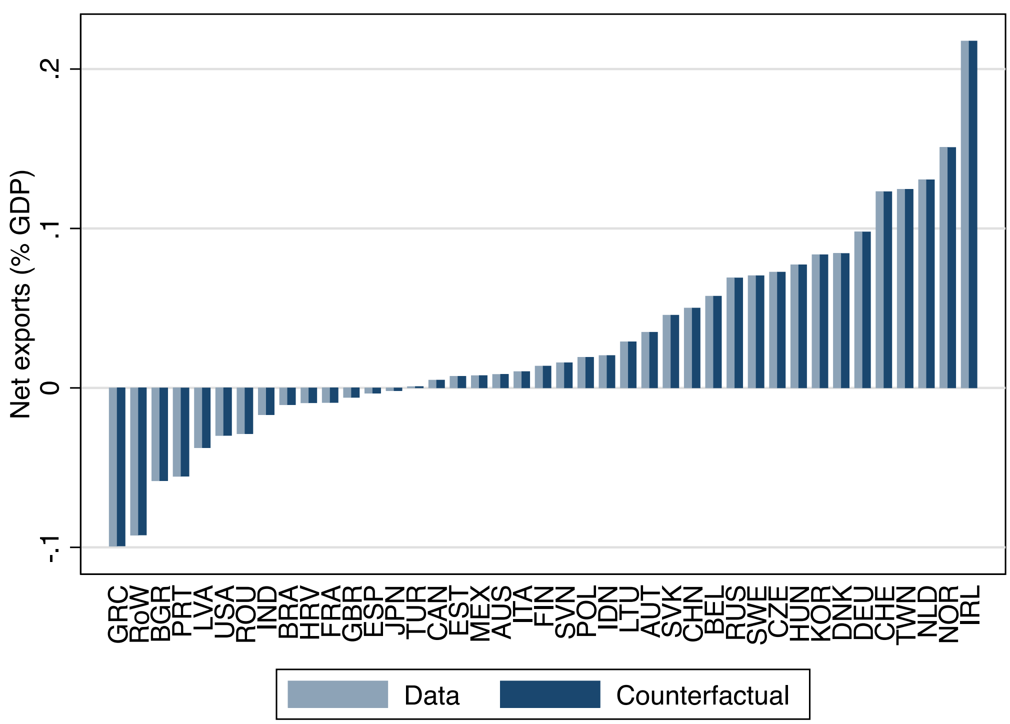
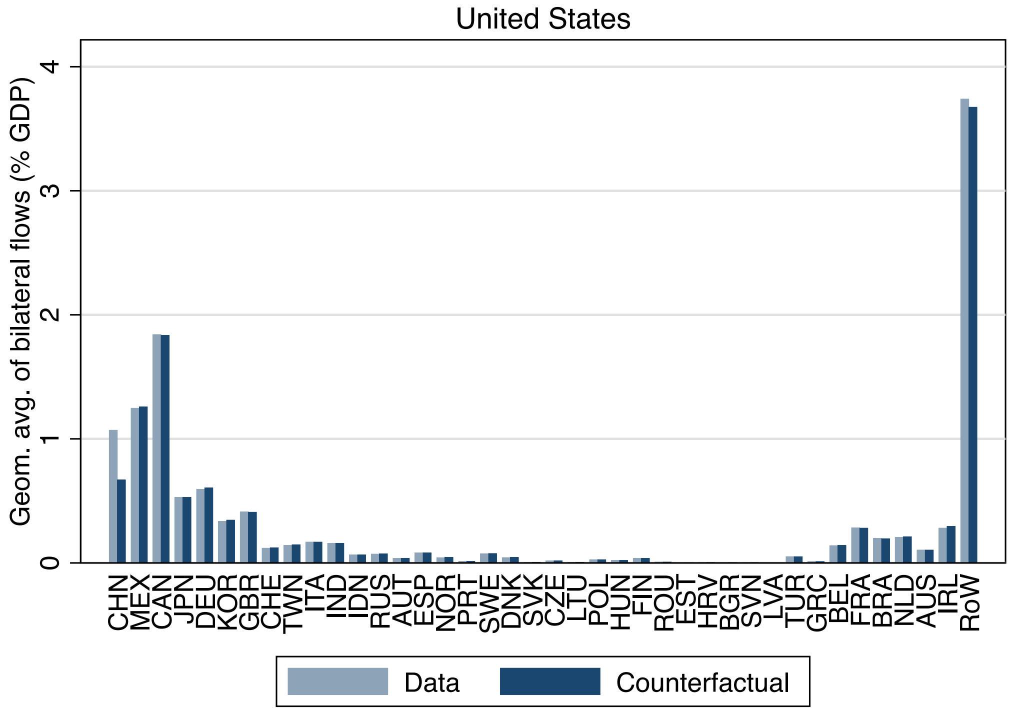
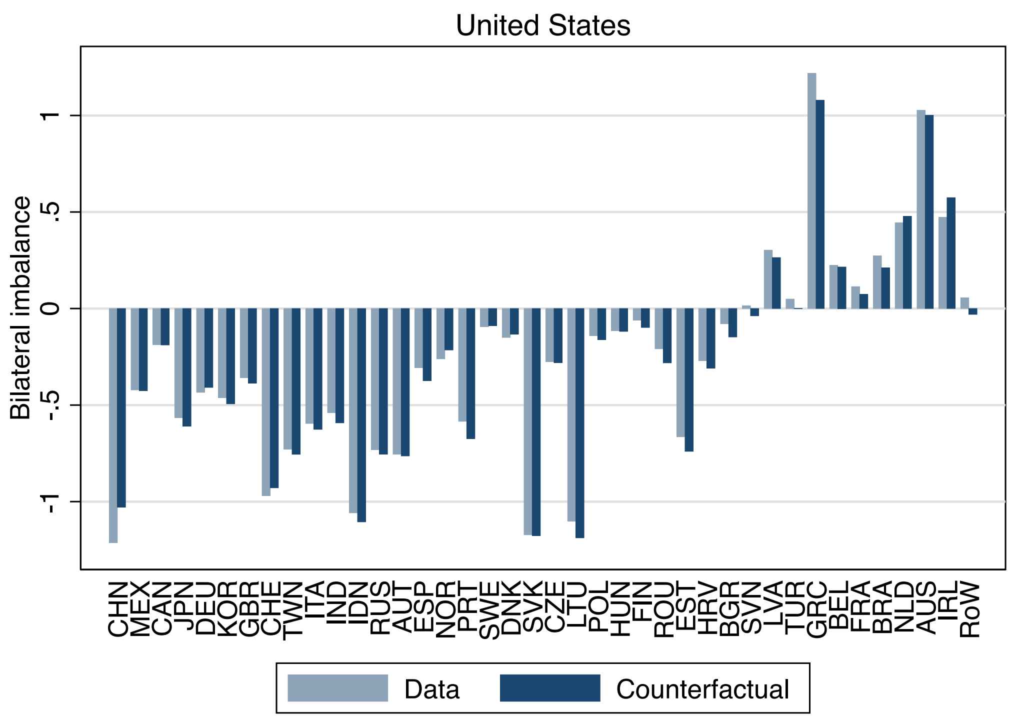


Figure A4: Aggregate trade balances in the wake of the USA-CHN trade war

Bars represent the aggregate net exports of the horizontal-axis country, expressed as a percentage of GDP. "Data" refers to actual net exports. "Counterfactual" refers to net exports in the steady state of the USA-CHN trade-war counterfactual, as described in Section 5.3 and Appendix A4. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.



Panel A: Changes in in the geometric average of trade flows (as % of GDP) with given trading partner



Panel B: Changes in the difference of bilateral trade flows relative to the geometric average of flows

Figure A5: Decomposing changes in U.S. bilateral net exports due to the USA-CHN trade war

The "geometric average of bilateral flows (% GDP)" refers to $100 \times \left(M_{n.USA,t} M_{USA,nt}\right)^{1/2} / P_{USA} Y_{USA,t}$; and the "bilateral imbalance" refers to $\left(M_{USA,nt} - M_{n,USA,t}\right) / \left(M_{n.USA,t} M_{USA,nt}\right)^{1/2}$, where $M_{n'nt}$ represents the total spending by country n on goods and services from n' in period t. "Data" refers to actual components of net exports. "Counterfactual" refers to components of net exports in the steady state of the USA-CHN trade-war counterfactual, as described in Section 5.3 and Appendix A4. Calibration on data from PWT 9.0 and WIOD (2016 release), average for the years 2010-14.

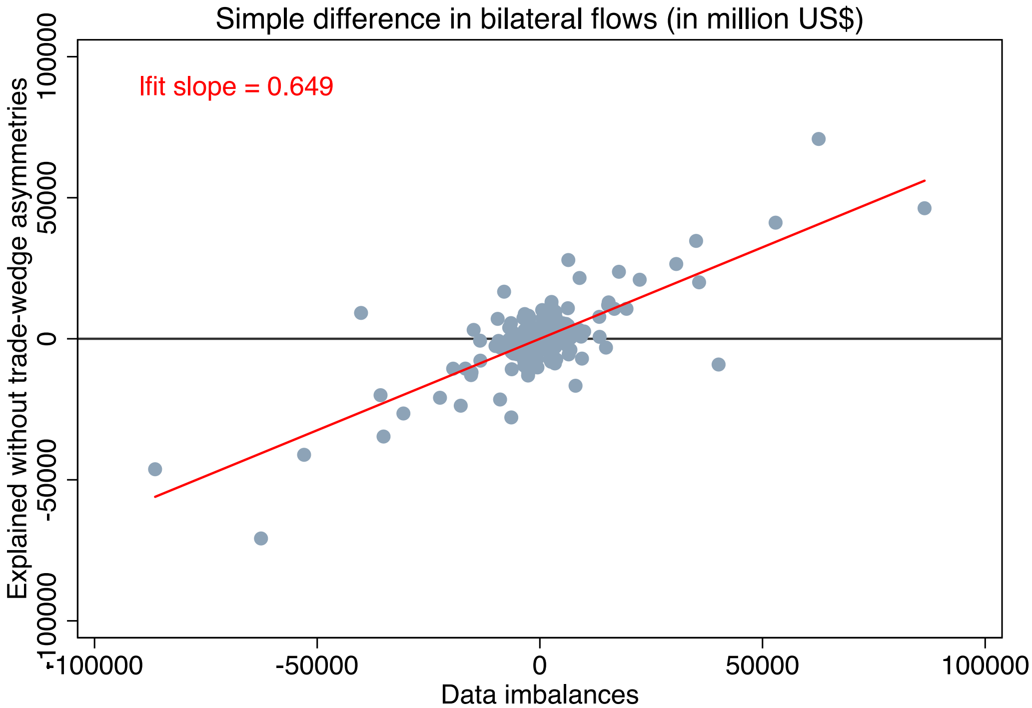


Figure A6: Accounting for country-pair variation in the simple differences of bilateral flows

The "simple difference in bilateral trade flows" refers to $M_{n'n} - M_{nn'}$, where $M_{n'n}$ is the value (in million US$) of imports by country n from n'. "Data imbalances" are the simple differences observed in the data. "Explained..." are the simple differences predicted on the basis of equations (47) and (48) in Appendix A4. All data is based on WIOD (2013 release), average for the years 1995-99. The data covers 37 individual economies and the rest of the world.

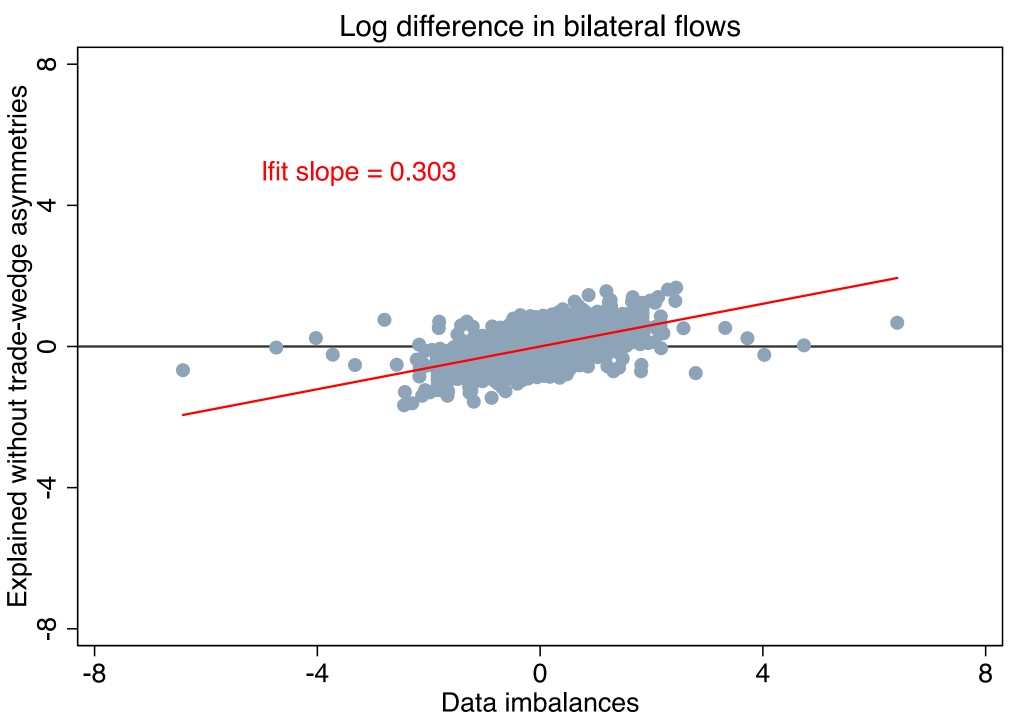


Figure A7: Accounting for country-pair variation in the log differences of bilateral flows

The "log difference in bilateral trade flows" refers to $\ln M_{n'n} - \ln M_{nn'}$, where $M_{n'n}$ is the value (in million US$) of imports by country n from n'. "Data imbalances" are the log differences observed in the data. "Explained..." are the log differences predicted on the basis of equations (47) and (48) in Appendix A4. All data is based on WIOD (2013 release), average for the years 1995-99. The data covers 37 individual economies and the rest of the world.